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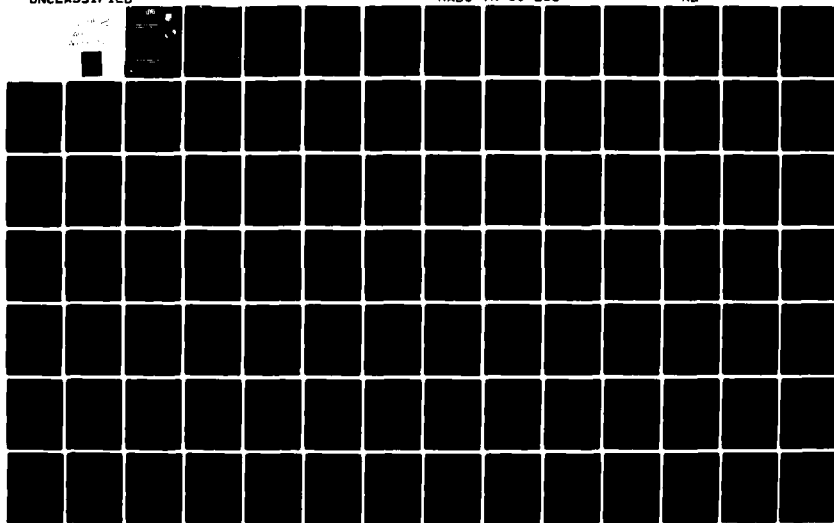
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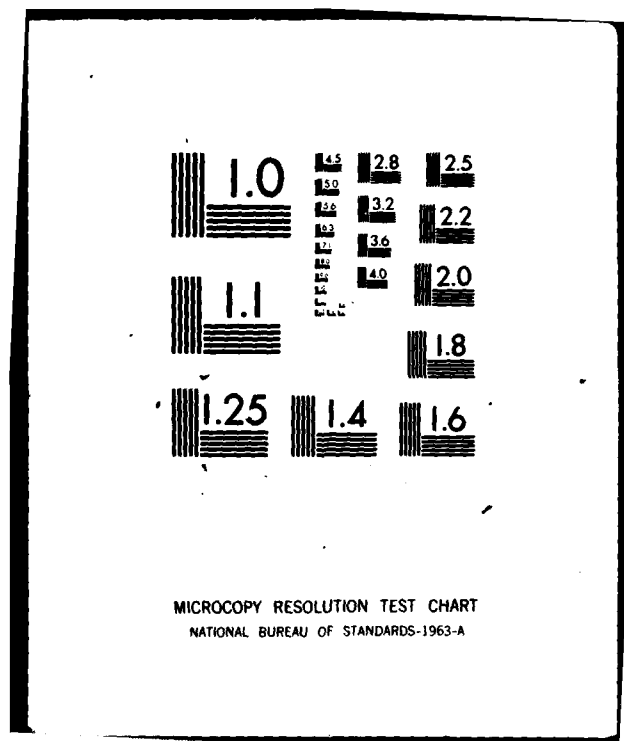
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RESEARCH OF SUBSONIC IN TUBULAR OUTLET

ONLINE COLLEGE OF TECHNOLOGY

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APPROVED FOR PUBLICATION

THIS REPORT CONTAINS
THE RESULTS OF RESEARCH
CONDUCTED AT THE
ONLINE COLLEGE OF TECHNOLOGY

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19. REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER RADC-TR-89-238	2. GOVT ACCESSION NO. AD-A089	3. RECIPIENT'S CATALOG NUMBER 702	
4. TITLE (and Subtitle) MODELING OF SHADOWS IN RADAR CLUTTER		5. TYPE OF REPORT & PERIOD COVERED Final Technical Report 1 Jun - 31 Dec 79	
7. AUTHOR(s) Bruce A. Black Mohammed Arozullah William Ladew		6. PERFORMING ORG. REPORT NUMBER N/A	
8. PERFORMING ORGANIZATION NAME AND ADDRESS Clarkson College of Technology Department of Electrical and Computer Engineering, Potsdam, NY 13676		9. CONTRACT OR GRANT NUMBER(s) F30602-78-C-0102	
11. CONTROLLING OFFICE NAME AND ADDRESS Rome Air Development Center (OCTS) Griffiss AFB NY 13441		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62702F 450611PE	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Same		12. REPORT DATE Jul 1980	
		13. NUMBER OF PAGES 114	
		15. SECURITY CLASS. (of this report) UNCLASSIFIED	
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A	
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited.			
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report) Same			
18. SUPPLEMENTARY NOTES RADC Project Engineer: William L. Simkins (OCTS)			
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Clutter Ground Clutter Shadowing → To be used as a...			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report presents the results of work done during June-December 1979 on investigating the applicability of the Forgy-Jancey and minimum spanning tree clustering algorithms to the problem of locating and characterizing shadowed regions in ground clutter. Certain preprocessing techniques were also investigated for reducing the amount of data prior to clustering. The two clustering algorithms were applied to both simulated and actual radar data, the latter provided by the Signal Processing -			

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Laboratory at RADC. The algorithms were run on the IBM 360/65 at Clarkson College using programs either written at Clarkson or obtained from the pattern recognition package ARTHUR.

The Forgy-Jancey algorithm was found to be flexible and capable of handling large data sets at moderate cost, but was inconsistent in its ability to detect the "natural" clusters in unknown data. The minimum spanning tree algorithm was more reliable in this regard, but the ARTHUR implementation was found to be costly in terms of required storage. The report contains numerous figures illustrating the application of the two clustering algorithms to various configurations of data.

Clustering techniques appear to hold promise for examining the structure of unknown clutter data, but the results must be interpreted with care, since a natural clustering is not always found. The primary result of the work to date has been the installation of the programs on the Clarkson College computer and the familiarization of the researchers with their use and limitations. It now remains to apply these programs to a wider class of data.

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EVALUATION

1. As future tactical and strategic sensors become more automated and unattended, their processing will increasingly treat the environmental scatter as information rather than "clutter" or interference. By inference from measureable quantities and statistics, the processor will recognize the existence of weather, chaff, discrete targets, homogeneous distributed areas, shadowing as opposed to specular reflection, and other environmental categories. This information will allow the system to adapt its waveform, energy budget, and detection/CFAR algorithms for optimum performance. This effort investigated algorithms which may be usable in such a recognition scheme.

2. Stress was placed on the strengths, weaknesses, and peculiarities of two promising algorithms when applied to the recognition of shadowed areas. The program has provided an excellent insight into the robustness and sensitivities to data format of each algorithm and the care required in the interpretation and use of algorithmic results. This report will be a useful reference in the development of clutter model and associated adaptive processing for future intelligent unattended systems.

William L. Simkins
WILLIAM L. SIMKINS
Project Engineer

MODELING OF SHADOWS IN RADAR CLUTTER

1.0 INTRODUCTION

This report presents the results of the work done during the period June-December 1979 on investigating the applicability of nonparametric clustering techniques to the extraction of features from radar clutter. The Forgy-Jancey [1] and minimum spanning tree [2] algorithms were investigated, with particular application to the problem of locating and characterizing shadowed regions in ground clutter. The significant result of the work is an exposition of the strengths and weaknesses of the two clustering techniques when applied to both simulated and actual radar returns. It is expected that the same strengths and weaknesses should appear in applications involving extraction of clutter features other than shadows.

The motivation for undertaking the present study of ground clutter is summarized in [3]. The need has existed since before the Second World War to extend the ability of radars to detect and identify targets of low cross-section in severe clutter. Initial efforts were concerned with increasing transmitter power, but for the past two decades the emphasis has been on development of the signal processing abilities of radar receivers [4]. The recent explosive developments in digital technology are expected to result in a new generation

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of sophisticated signal-processing radars, able to take advantage of random-access memories and high-speed computational ability. The need to specify how such radars are to be designed and used provides a requirement for an improved understanding of the structure of backscatter clutter.

There are several indications that the present understanding of backscatter clutter is inadequate. First, clutter measurement efforts concerned with various terrain and cultural features have produced data of only limited consistency. In particular, it is not uncommon to find a 15 to 20 dB spread in measurements of intensity returns made at different times from supposedly identical terrain. Second, there has been only limited success in predicting backscatter from topographical maps, even though the terrain relief, surface features, and ground cover are specified on the maps. Finally, radars employing signal processing systems, such as CFAR, that are based on particular clutter models [5] have frequently been found to perform more poorly than analysis based on the clutter models would suggest.

There are several possible reasons for the poor consistency of measurement data and the difficulty of predicting backscatter intensity from terrain descriptions. First, it is likely that backscatter is highly sensitive to surface parameters such as moisture, temperature, and wind

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velocity, that are difficult to measure simultaneously with the radar return, and have not always been included as a part of the recorded "ground truth". Second is the possibility that the clutter returns vary with the parameters of the radar itself in ways that have not yet been clearly recognized.

Much of the radar signal processing effort to date has been based on the assumption that clutter intensity can be modeled by a random variable. The motivation to develop such a model is strong, because of the success of design methods using the Neyman-Pearson decision rule in connection with a gaussian or rayleigh model for thermal noise. Such decision-theoretic methods could be easily extended to detection of targets in clutter, if only the probability density function of the clutter intensity could be found. It is likely, however, that ground clutter is too heterogeneous to be represented by a single random variable, or possibly even by a single type of random variable. It is therefore necessary that an examination of the structure of radar clutter be carried out in a way that does not rely on knowledge of a probability distribution.

Methods for investigating the structure of unknown data have been developed in connection with research in taxonomy [1,6] and chemistry [7]. These methods are referred to as either classification or clustering methods, depending on whether or not a statistical structure is assumed for the unknown data. The classification methods assume that each data

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entity belongs to one of several possible categories, each category characterized by a probability density function. Most classification algorithms require training on data whose classification by category is known. The training allows the algorithm to estimate the density functions corresponding to the various categories. The estimated density functions are then used in classifying future unknown data. In contrast, clustering methods do not assume that categories of data can be characterized by density functions. Instead, data entities are grouped into clusters by examining the distances between entities based on some suitable measure of distance. A detailed discussion and comparison of many available classification and clustering methods is presented in [6].

In the present research the view has been taken that ground clutter from arbitrary sources can not be reliably represented in terms of probability density functions [8]. Attention was therefore focussed on an investigation of the various clustering methods. The research has proceeded along three paths: first an investigation of the Forgy-Jancey clustering algorithm, second an investigation of the minimum spanning tree algorithm contained in the program package ARTHUR, and, finally, an investigation into some pre-processing techniques applicable to either of the clustering algorithms.

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A description of the Forgy-Jancey algorithm along with the results obtained from applying it to a variety of simulated and actual clutter returns is presented in Section 2. Although the Forgy-Jancey algorithm is well-known, it was necessary to create our own programs, and to devise from scratch the necessary input-output and display routines. Investigation of the minimum spanning tree clustering method is described in detail in Section 3. This investigation began with acquisition of the ARTHUR program package [7] from the University of Georgia. The necessary job-control language was created, and the ARTHUR package compiled so that it is currently available on the Clarkson College computer. The minimum spanning tree algorithm was tested on some of the same simulated data as was devised for the Forgy-Jancey tests. Section 4 contains the results of some pre-processing efforts that were tried on actual clutter data. The pre-processing was motivated by the need to reduce the quantity of data to a manageable amount for the ARTHUR package. The pre-processing is typical of the steps that would be taken in an actual clustering effort, and provided an indication of the amounts of CPU time, programming time, and costs that are involved in such steps. Section 5 contains an overall summary and the conclusions.

Sections 1, 2, and 5 were written by Bruce A. Black, Section 3 by William Ladew, and Section 4 by Mohammed Arozullah.

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2.0 THE FORGY-JANCEY ALGORITHM

2.1 The Algorithm

This section discusses the operation of the Forgy-Jancey clustering algorithm, and the tests that were made on simulated and actual radar data to probe the strengths and weaknesses of the algorithm as a tool for identifying the structure of ground clutter from shadowed terrain. The computer program for the Forgy-Jancey algorithm was obtained from Fordon [9]. Several modifications to the algorithm were made to allow greater flexibility in manipulating, saving, and displaying the input and output data. The algorithm employed in all of the tests is due to Forgy [10]. Jancey's version [11] contains a heuristic to avoid local minima, but was not needed in the present application. The basic Forgy-Jancey program along with the modifications is presented in block-diagram form below. A listing of the important subroutines is presented in an Appendix.

Figure 2.1 is a flowchart showing the operation of the Forgy-Jancey algorithm. This algorithm forms clusters of data entities, where each data entity is a vector of NV components. The number NV of components in a data entity (number of variables), the number NE of data entities, the number NC of

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clusters, and the coordinates of the cluster centroids must all be specified by the user. In this version of the algorithm the number NC of clusters cannot be modified by the program; the program can neither create nor delete clusters. In operation, the program will partition the NE data entities into NC clusters. A measure of the compactness of the clusters that is used as a figure of merit by the program is the total summed deviations. For a given partition of the data into clusters, this is the sum over all the entities of the distance between each entity and the centroid of the cluster to which it is assigned.

Forgy's algorithm begins with an initial set of NC cluster centroids. In the main loop of the program, each data entity is assigned in turn to the nearest cluster centroid. When all of the entities have been assigned, the cluster centroids are recomputed. Each iteration requires a complete pass through the data. It is easily shown that a pass through the main loop cannot increase the value of the total summed deviations, so that the algorithm must converge to at least a local minimum. In each pass through the main loop the program counts the number of entities whose cluster assignment is changed. When the number of changes falls below a user-supplied parameter MINREL, the program halts. Except where otherwise noted, programs were run with MINREL equal to zero, corresponding to complete convergence.

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The distances between entities and cluster centroids required by the algorithm are computed by a user-supplied subroutine DIST. Because this routine is externally supplied, the distance function can be configured to meet the specific application. In particular, it is possible to base the distance calculation on a subset of the components of the data entities. Both euclidean and non-euclidean distance measures are allowed.

The program path for the Forgy-Jancey algorithm is shown in Figure 2.2. The program MAIN and the subroutines EXEC, USER, RESULT, KMEAN, and USROUT were all supplied or modified as a part of the present effort. The program supplies as outputs:

1. A raw membership list, listing cluster membership for each data entity.
2. A sorted membership list, giving for each cluster the sequence numbers of its members.
3. A sorted data file. The data entities themselves are sorted into groupings by cluster membership. This file can be saved on disk, thus allowing the entities forming a single cluster to be isolated for further processing.
4. The program prints the final centroid locations for each cluster, the number of data entities belonging to each cluster, and the value of the total summed

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deviations.

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2.2 Testing

For initial testing of the Forgy-Jancey algorithm, a set of 10,000 data entities representing a 100-point by 100-point "scene" was generated. Each data entity was a three-vector, (x,y,I) , where x and y represent the position of the entity in rectangular coordinates and I represents the intensity of the radar return from position (x,y) . Two rectangular regions were set aside in the 100x100 array to represent "shadows", one region occupying 651 points and the other occupying 121 points. The test scene is depicted in Figure 2.3.

For the initial test of the algorithm, the value 0 was given to the intensity component of data entities in the shadowed areas, while the value 1 was given to the intensity component of data entities in the unshadowed area. The algorithm was applied with the number of clusters NC set equal to two. The distance function $DIST$ was set to compute the distance between two entities as the magnitude of the difference between their intensities. The output of the program is shown in Figure 2.4. The points marked 1 correspond to cluster 1, while the points marked with a dot correspond to cluster 2. Note that cluster 1 contains exactly the entities in the shadowed array.

A second clustering was carried out using only the entities in cluster 1 as data. This time the function $DIST$ was

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changed to compute the distance between two entities as the euclidean distance between their positions. The program was run with $NC = 2$. The output is shown in Figure 2.5. In this figure the points marked with a dot were not included in the input data. The points marked 1 and 2 represent the two clusters obtained by the algorithm. Note that these correspond exactly with the two shadows.

A second, more demanding, test of the Forgy-Jancey algorithm was made using random numbers as simulated intensity values. A program was written to produce a sequence of numbers having a rayleigh distribution. The distribution parameter sigma is entered as an input to the program. To establish the test data, 10,000 rayleigh-distributed numbers were generated with $\sigma = 1$. These numbers were assigned as intensity values to the data entities in the 100 by 100 array. Next a sequence of rayleigh-distributed numbers was generated with sigma much greater than one. These numbers were added to the intensity values of all the data entities outside the two shadowed areas. Thus a set of test data was established to represent two shadows containing only rayleigh-distributed thermal noise in a larger region of brighter rayleigh-distributed clutter.

As in the previous test, the Forgy-Jancey algorithm was applied twice, once to separate the low-intensity shadows from the bright clutter background, and a second time to separate

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the low-intensity cluster into individual shadows. The result the first clustering is shown in Figure 2.6. The bright clutter in this case has sigma set to 10,000. In the figure, the dark cluster is indicated by ones and the bright cluster by twos. Note that the dark cluster includes many points belonging to the bright region. In fact, the algorithm was unable in this case to locate the dark region; the program was instructed to find two clusters, and it did so by splitting the bright data half. The shadow data are simply included in the darker of the two clusters.

To provide a greater apparent separation between the dark and bright data, and to provide an example of the use of coordinate scaling, the program was modified to interpret intensity values in decibels. This was effected by employing the program USER to replace the intensity values I for each entity by their logarithms $\ln I$ as the entities were read into core. The result of a clustering done on the rayleigh data using this logarithmic transformation is shown in Figure 2.7. Perfect separation of the dark and bright regions was obtained. Figure 2.8 was obtained using only the dark cluster as data. The dark cluster was split on the basis of position into the two clusters shown by points marked 1 and 2.

The gap between the dark and bright intensity values can be reduced by changing the value of sigma used in generating

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the bright rayleigh data. To create a more demanding exercise for the algorithm, the data set was recreated with sigma equal to 50. Logarithmic scaling of the intensity values was again used. Figure 2.9 shows the result of clustering for light and dark intensity regions. Points in the dark cluster are indicated by ones, and points in the bright cluster are indicated by twos. Note that a number of bright points have been misclassified by being included in the dark cluster. It would be expected that statistical variation among the intensity values of the non-shadow data would lead to some "bright" points with intensity values that are in fact as low as the values of the intensities of the shadow data. The number of misclassified points shown in the figure corresponds roughly with the number that would be expected on statistical grounds.

Problems with convergence of the Forgy-Jancey algorithm were encountered for the first time in generating the clusters shown in Figure 2.9. To generate this figure the algorithm was halted using $\text{MINREL} = 100$; i.e. on the first pass for which fewer than 100 data entities were reassigned. Figure 2.10 shows the result of running the algorithm all the way to convergence, a process which required nearly five minutes of CPU time. It is interesting, and somewhat surprising, to note that the dark cluster of Figure 2.10 includes even more misclassified "bright" points than does the dark cluster of

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Figure 2.9.

The dark cluster of Figure 2.10 was used as the data base for the second clustering pass, in which individual shadows were separated. Figure 2.11 shows the result of clustering by position with NC equal to two. In this case the two shadows were correctly separated, but each cluster consists of a dense core, corresponding to the actual shadow, surrounded by a sparse "halo" of points. In an attempt to separate the shadows from their halos, several clustering passes were made on the data with NC greater than two. Figure 2.12 shows the result of clustering by position when NC equals three. The points marked zero are excluded from the data set. The three clusters are indicated by points marked 1, 2, and 3, respectively. (Cluster two is in the upper right-hand corner of the figure.) Note that the actual shadows still form the cores of separate clusters, but that both are still surrounded by halos. Figures 2.13, 2.14, and 2.15 are the results of clustering with NC respectively equal to four, five, and six. Figure 2.16 shows the case with NC equal to seven. One of the shadows has been split into two clusters, marked 1 and 7 in the figure. This is an undesirable result, from which two lessons can be learned: first that the Forgy-Jancey algorithm will find as many clusters as it is instructed to, whether or not these clusters are meaningful, and second, that increasing the number of

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clusters is not an effective method for removing the halo from a dense core of points.

Identifying the value of NC that corresponds to the number of clusters actually present is difficult when dealing with unknown data, especially data of high dimensionality that cannot be readily plotted. Jancey [1] suggests beginning with $NC = 1$ and running the algorithm repeatedly with $NC = 2, 3$, etc. As the number of clusters increases, the value of the total summed deviations obtained at convergence will decrease. As "natural" clusterings are obtained, there should be significant drops in the value of the total summed deviations. An example of this effect is presented in [1]. Figure 2.17 shows the values obtained for total summed deviations in the above rayleigh example when $NC = 1$ through 7. Note that the most significant drop occurs when NC is raised from one to two.

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2.3 Removal of Outliers

Fordon [9] suggests a modification of the Forgy-Jancey algorithm to allow rejection of data entities that are too far from any of the cluster centroids. A data entity can be isolated if it satisfies the relation

$$|D_{\min} - D_{\text{avg}}| < (\text{OUTLYR}) \times D_{\text{avg}}$$

where D_{\min} is the distance between the entity and the nearest cluster centroid and D_{avg} is the average of the distances between the data entity and each of the cluster centroids. The parameter OUTLYR is assigned a value between zero and one by the programmer. A value of zero results in no entities being isolated, while a value of one results in every entity being isolated. The main loop of the Forgy-Jancey algorithm was modified so that whenever an isolated entity is encountered it is designated as the centroid of a new cluster. This allows the program to increase the number of clusters. A provision was included to limit the number of clusters to a programmer-specified maximum, since CPU time was found to increase dramatically with the number of clusters. In interpreting the results of a clustering run, the programmer has the option of disregarding all newly-formed clusters as representing outliers; i.e. sets of anomalous entities that lie outside the known clusters, or of accepting all of the clusters in the expectation that the program has found a more natural

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number of clusters than the programmer originally specified.

An example of a clustering run using the modified Forgy-Jancey algorithm is shown in Figure 2.18. The data set is the 100x100-point array depicted in Figure 2.3, with each entity having an intensity value of zero or one. Three outliers were created, having intensity values of zero, and lying outside the simulated shadows. The Forgy-Jancey algorithm was run twice, once to separate out the low-intensity points and once to cluster these points into individual shadows. Figure 2.18 is the result of the second run. To generate this figure, the program was started with $NC = 2$ and $OUTLYR = 0.6$. The program responded by creating two additional clusters, identified in the figure by the numbers 3 and 4. Although the program successfully located the three outlying points, it should be noted that the value used for the parameter $OUTLYR$ is fairly critical. The program was unable to locate all of the outliers when run with $OUTLYR = 0.4$.

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2.4 Testing of Actual Radar Data

A tape containing a segment of a PPI display was provided by the Signal Processing Laboratory at RADC, courtesy of William L. Simkins, Jr. The tape contains data in essentially the same format as the simulated data described above: each data entity is comprised of a set of three components representing x and y position and intensity. The data were created by quantizing a photograph of the original CRT display, and in consequence the intensity scale of the data is compressed by the responses of the CRT phosphor and the film. Figure 2.19 depicts one quadrant of the radar data. The grey scale used in the figure consists of the symbols (W,*,A,I,+,-,.,blank), in order from highest to lowest intensity. Figure 2.20 shows the low-intensity regions of the quadrant of data. The set of low-intensity entities was used as a data base for the Forgy-Jancey clustering algorithm. Numerous runs were made, using various values of input parameters. A typical output is shown in Figure 2.21. To generate this output twenty-one initial cluster centroids were chosen, corresponding roughly to the centers of the clusters visible in Figure 2.20. The outlier parameter was set to OUTLYR = 0.9, and the algorithm was stopped when fewer than 33 entities changed cluster membership (MINREL = 33). The program ran for nearly four minutes and generated a total of

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twenty-five clusters.

Examination of Figure 2.21 reveals the twenty-five clusters, designated by the numbers zero through nine and the letters A through O. A close examination of this Figure reveals that many of the clusters found by the program do not correspond to the natural clusters evident in Figure 2.20. In particular, attention is called to cluster K, which is composed of the adjacent parts of four natural clusters, clusters C and O, which split a single natural cluster, cluster 2, which contains some entities that should properly belong to cluster 3, and cluster D, which encroaches on the territory of clusters C and O.

In processing the actual radar data, the Forgy-Jancey algorithm had a great deal of difficulty in locating the natural clusters. It is likely that this difficulty stems from two sources: the highly irregular shapes of the natural clusters, and the fact that the natural clusters vary greatly according to size. It is believed that the total-summed-deviations figure of merit used by the algorithm tends to emphasize the compactness of clusters. Thus whenever a cluster becomes too long and narrow, the algorithm will split it into two smaller clusters. The procedure used by the program for generating new clusters tends to result in clusters of about equal size. Hence the difficulty in dealing with a data set that contains clusters as small as cluster 7 and as

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large as cluster 6.

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2.5 Conclusions

The Forgy-Jancey clustering algorithm is a powerful tool whose principle advantages seem to be its generality and simplicity. The generality results from the ability of the algorithm to handle data sets of essentially any size, consisting of data entities of any dimension. The number of clusters that the algorithm can handle is also essentially unlimited, and the programmer is free to prescribe arbitrary coordinate scaling and an arbitrary distance measure. The simplicity of the algorithm is helpful when modifications are needed. In carrying out the present study it was necessary to add several input and output routines, and to modify the main loop of the algorithm to incorporate the ability to generate new clusters.

The drawbacks to using the Forgy-Jancey algorithm are clearly illustrated in Section 2.4, particularly in Figure 2.21. The Forgy-Jancey algorithm is known to be capable of finding clusters that bear no relation to any natural clustering [10], and must be used with extreme care on unknown data that can not be visually inspected. Some of the difficulty in locating the natural clusters in Figure 2.21 can be attributed to the procedure used for generating new clusters. Without this procedure, however, it is necessary to specify the number of clusters in advance. Jancey's procedure

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for monitoring the total summed deviations offers one method by which the number of natural clusters might be determined.

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3.0 MINIMAL SPANNING TREE ALGORITHM

3.1 Introduction

In this section we describe the minimal spanning tree algorithm [2] for clustering data. This graph-theoretic method differs greatly from the Forgy-Jancey method described in the previous section. We used an implementation of the MST (minimal spanning tree) algorithm in our investigation obtained in the ARTHUR subroutine package. ARTHUR is a general package of data manipulation and analysis subroutines that was obtained from the University of Georgia. The MST subroutine in the package is called TREE and requires use of a distance subroutine DIST, plus input and output utility subroutines also contained in the package. ARTHUR will be discussed further in this section, along with the description and discussion of TREE. Before we examine how TREE clusters our data, we must first discuss the MST algorithm and how it can be used for clustering.

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3.2 Minimal Spanning Trees

A minimal spanning tree is an undirected graph that includes all the given data points, has no loops or cycles, and has a minimal distance over all the edges in the tree. The MST can use any distance metric to describe how close (or similar) the data points are, but the important point is that the resultant tree will have the smallest total distance of any of the possible spanning trees. The choice of the distance metric makes this method general for any type of data; however, in our study we only considered euclidean distance for x-y data. This is because we were only doing x-y clustering in this phase of our study. A different form of metric could be used for some other clustering, such as intensity clustering. The ARTHUR MST algorithm clusters data by finding "inconsistent" edges in the MST; the tree itself does not contain clusters, but the algorithm points out edges that when deleted would give a natural clustering. This method of forming clusters eliminates one of the major problems encountered in using the Forgy-Jancey algorithm, namely that we must tell it how many clusters to find, but the MST clustering algorithm then needs some form of information describing what an inconsistent edge is. The factors we use to determine whether an edge is inconsistent depend on the average length of the neighboring edges, where we can specify how deep along the tree a neighboring edge is. We

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also need to know how many standard deviations from the average the edge is question is. The edge is cut based on these parameters, if the edge is more than the specified number of standard deviations from the average.

This method of forming clusters is general in as much as the distance metric is general and the clustering criterion is relative to distances in the tree. This method of choosing clusters based on inconsistent edges in the minimal spanning tree will work well on many types of data, as shown by Zahn [2]. After the tree is formed, the inconsistent edges are found and deleted and the connected groups that are left are the clusters. This means that we can form any number of clusters, not just a predetermined number or range of clusters. Also, we can find the tree just once, and try several different sets of clustering parameters on it, without the expense of finding the MST each time.

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3.3 ARTHUR and the MST

We used the TREE routine in ARTHUR to cluster data using a minimal spanning tree. TREE can be given three parameters, the DEPTH of the neighbors, a FACTOR used in finding inconsistencies, and a SPREAD of the number of standard deviations allowed before an edge is inconsistent. An edge is inconsistent if its length is greater than FACTOR times the length of the neighboring edges, or if it is more than SPREAD standard deviations longer than the average of the neighboring edges, where neighboring edges are all edges within DEPTH edges from the edge being tested [7]. A copy of the ARTHUR documentation is contained as an appendix in Fordon [9]. In using TREE, the data must be input to ARTHUR using one of its utility routines. The distance matrix containing the distance between every pair of data points must be found and stored using the DIST utility routine, and then TREE is called. Part of a test run of ARTHUR and TREE is shown in Figure 3.1, showing how TREE outputs the MST as a list of nodes and neighbors. The resulting clusterings are shown in Figures 3.2, 3.3, and 3.4, as lists of entities (they call them patterns) belonging to the various clusters. These clusterings were all done on the same MST in the same run of ARTHUR; recalculation of clusters with different parameters does not require recalculation of the distance matrix or the MST. The main

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limitation is that in examining N data entities, we require on the order of N^2 units of storage for the distance matrix, and of course the amount of time to compute all the distances. This is significant in that if we double our number of points, we need four times the storage and computer time to do the same processing. For example, a 10 by 10 picture has 100 points, and needs 10,000 words of storage for its distance matrix; if we increase the picture size to 100 by 100, we have 10,000 points and need 100,000,000 words to store the distance matrix. So to enlarge a picture by a factor of 10 requires a 10^4 increase in memory.

A temporary limitation of TREE is that it only prints a description of the MST in terms of the nodes and edges as in Figure 3.1, and clustering cannot be displayed other than in a list of cluster members. The cluster membership is not output in an ARTHUR format file so we cannot display the clustering using one of ARTHUR'S plotting routines.

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3.4 Actual Clustering Using TREE

In order to test the clustering ability of TREE, we used data previously used in the Forgy-Jancey testing. We took part of one of our rayleigh data files, namely cluster number 2 from Figure 2.11, and converted it to ARTHUR data format. This picture consists of 218 data entities, shown as 1's in Figure 3.5. We want to isolate the obvious group of 121 entities from the surrounding outlier entities. We ran ARTHUR on this data, found the distance matrix using euclidean distance, and called TREE. TREE found the minimal spanning tree, shown in Figure 3.6, and clustered the data according to several different sets of parameters. The clustering formed by the default parameters of DEPTH=3, FACTOR=2 and SPREAD=0, as in Figure 3.2, did eliminate some of the outliers from the desired cluster, but left 207 entities in the cluster, which is not very close to our desired 121 entities in the cluster. These parameters did not form many extra clusters; only five clusters were found, separating only 11 outlier entities from the main cluster.

By trying only a few different combinations of parameters, we made the clustering much better. Using DEPTH=1, FACTOR=1, and SPREAD=1, we found 33 clusters, shown in Figure 3.3. This clustering put 132 entities in the main cluster, eliminating almost all the outliers. It removed 86 of a possible 97 outlier entities from the main cluster. Using the same

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parameters as before, but setting SPREAD=0.5, we obtained the best results as shown in Figure 3.4. We found 37 clusters, and the main cluster had only two outlier points included in it, for a total of 123 points in that cluster. We were therefore able to eliminate 95 of 97 outlier entities. This clustering is drawn out in Figure 3.7, shown as the remaining edges in the tree, with all of the clusters circled to identify them.

This clustering differs from possible clusterings by the Forgy-Jancey algorithm in several ways. First, it cannot split up dense clusters because it attempts to cut edges only where they are not dense. Also, since this is a single pass clustering, the decisions are made once, not iteratively updated. This means that there are no convergence problems with the resulting waste of computer time. Again, since we need not choose in advance how many clusters to find, we eliminate the problem of re-running the program with different numbers of clusters until an optimal number is found. Instead, the program will find the appropriate number of clusters, given the parameters for cutting inconsistent edges.

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3.5 Conclusions

The TREE routine can create clusters from noisy data, as shown in Figure 3.7, without problems such as the splitting of desired clusters found with the Forgy-Jancey clustering. However, TREE in its present form is relatively expensive in both time and storage required. Part of this expense is due to the overhead involved in using the ARTHUR subroutine package, but using ARTHUR is worthwhile because it gives us a powerful and flexible system of programs, rather than a stand-alone MST program. ARTHUR provides us with its flexible input routine, and has built-in routines to do scaling on the data, and even can orthogonalize data that is not orthogonal. It also has a histogram plotter to check the data distribution, three different data plotting routines, and several classification subroutines besides TREE, such as a bayesian classifier and a hierarchical classifier. A stand-alone MST program might be more efficient, but would take substantial programming effort and would sacrifice all those valuable subroutines. The space expense is due to the N^2 size of the distance matrix, which presently limits maximum size of the data set that can be analyzed. However, ARTHUR can store data in both memory and disk dynamically by swapping parts of the data set between core and disk, saving memory at the cost of more disk I/O operations.

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TREE is more flexible than Forgy-Jancey because it does not have to be told how many clusters to find. In addition, Zahn [2] suggests a variety of alternative schemes for dividing a minimum spanning tree into clusters, each of which might be useful for a different pattern of data entities. If some of these schemes were to be incorporated into the MST subroutine, it would significantly enhance the usefulness of the minimum spanning tree as a clustering technique.

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4.0 PREPROCESSING TECHNIQUES

4.1 Introduction

In this section we describe a few preprocessing techniques used on the data before applying them to the clustering algorithms discussed in the preceding sections. The preprocessing techniques used are:

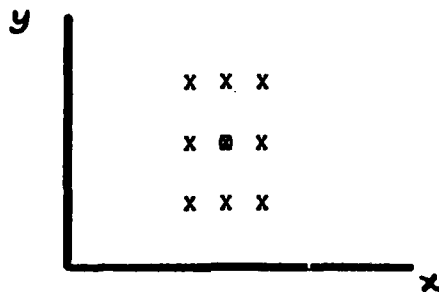
- a) point-to-point local variance
- b) point-to-point local gradient
- c) radial derivative

Of all these preprocessing techniques the radial derivative is the most promising one. These techniques were applied to the compressed digitized radar data provided to us by RADC and shown in Figure 2.19. In each case we applied the technique and examined the output data for clues for identification of bright and dark areas. Results obtained for each technique are discussed individually in the following. For each of these techniques we used half of the picture provided as otherwise the amount of data to be processed was too large.

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4.2 Point-to-Point Local Variance

The idea behind this method is that probably the variation of the intensity of the radar return will be very small inside a shadow and it will be large in the peripheries of shadows. For each point in the picture, variance was calculated by considering nine neighboring points on the left-right and above and below this point as shown below



We first calculated the average intensity \bar{I} for these nine points. Then we calculated the local variance by using the formula

$$\text{Variance} = \frac{\sum_{j=1}^9 (I_j - \bar{I})^2}{9}$$

where I_j indicates intensity at the j -th point.

Then these variances were plotted on an eight level grey scale using the following symbols: (W,*,A,I,+,-,.,blank) in descending order of the value of variance (W represents the highest and blank represents the lowest values of the

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calculated variances). This plot of the variances is shown in Figure 4.1.

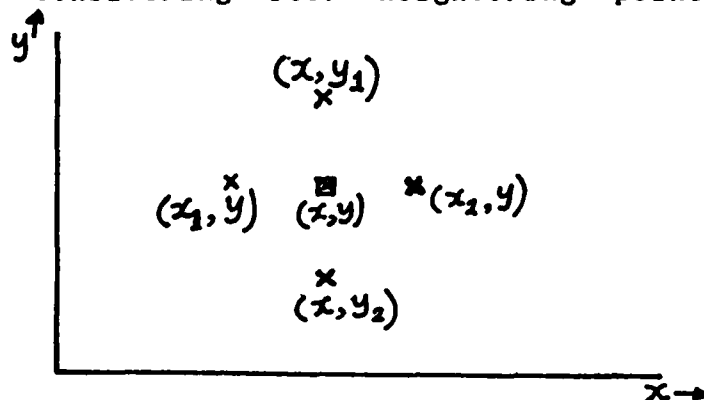
An examination of this figure reveals that the shadowy areas do have small variances and the edges have large variances. However; some areas with constant but high intensities also have small variances. Hence it appears that the local variance alone is not sufficient for clear cut identification of shadows. Other information like intensity and edge information may have to be considered together with the local variance. Further, with this local variance method all directional information i.e. the variation of intensity with distance is lost.

For an 128×128 point data set computation of local variances needed 33 seconds of CPU time. The storage requirement was 2×128^2 bytes, 128^2 bytes for the original array and 128^2 bytes for the calculated variances. We used 200 kilobytes of storage and it was sufficient. Expense for one run was \$2.22.

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4.3 Point-to-Point Local Gradient

The idea behind using local gradient was that there should be higher variation of intensity on the edges of shadows than inside them. For each point of the array local gradient was calculated by considering four neighboring points as shown below.



By using the formula,

$$\text{local gradient} = \sqrt{(I_{(x_2, y)} - I_{(x_1, y)})^2 + (I_{(x, y_2)} - I_{(x, y_1)})^2}$$

where $I_{(x, y)}$ represents the intensity at the point (x, y) . The calculated local gradients were plotted over an eight level grey scale using the same symbols as in the case of local variance. This plot is shown in Figure 4.2.

An examination of Figure 4.2 shows that in the case of local gradient also shadows and high constant intensity areas have low gradients. The edges, however, showed larger gradient. Hence the local gradient above also can not be used to identify shadows conclusively. Other information like the

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intensity, needs to be considered together with gradient.

For a 128 x 128 array of data points it took 25 seconds of CPU time to compute gradients. Storage requirement was also 2

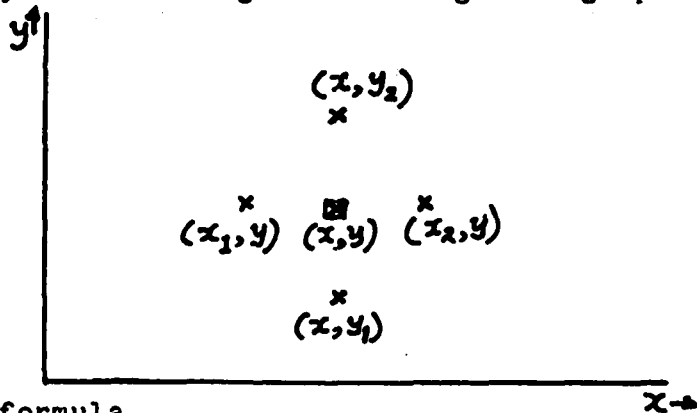
x 128² bytes. An allocation of 200 kilobytes was sufficient. Expense for one run was \$1.91.

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4.4 Radial Derivative Method

In this method derivatives were calculated along radial lines along those of the radar beam starting from the location of the radar as shown by the X in Figures 4.3 and 4.4. The idea behind using radial derivatives is that as the radar beam travels in radial directions, the variation of intensity in the radial direction will be a better measure of the reflective nature of the objects illuminated by the radar. Also any object intercepting the radar beam will produce a shadow in the radial direction.

For each point of the data array radial derivative was calculated by considering four neighboring points as shown below



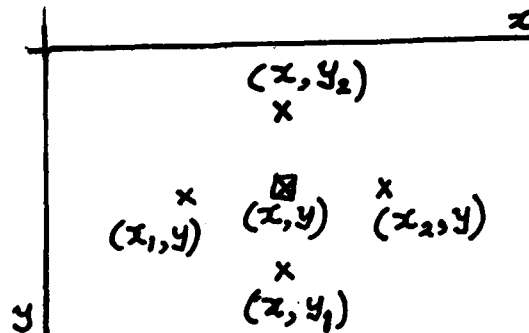
by using the formula

$$\text{Radial Derivative} = \frac{(I(x, y_2) - I(x, y_1))|y| + (I(x_2, y) - I(x_1, y))|x|}{\sqrt{2(x^2 + y^2)}}$$

for the points in the first quadrant. This formula has to be

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modified for other quadrants.
For example for the points in the fourth quadrant as shown, the radial derivative is given by



$$\text{Radial Derivative} = \frac{(I_{(x,y_1)} - I_{(x,y_2)})|y| + (I_{(x_2,y)} - I_{(x_1,y)})|x|}{\sqrt{2(x^2 + y^2)}}$$

These radial derivatives were plotted on a seven level grey scale using the following symbols.

< -30
 -30 =< @ < -15
 -15 =< - < - 5
 - 5 =< Blank < 5
 5 =< + < 15
 15 =< A < 30
 30 =< W

the plots are shown in Figures 4.5 and 4.6.

An examination of Fig. 4.5 reveals that:

1. All dark regions have low radial derivative

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2. Range marker showed up.
3. Shadows were marked by the following characteristics: in front of the shadows we observed regions of high radial derivatives (cause of shadow) followed by regions of low radial derivatives (edges of shadow) further followed by regions of lower radial derivatives (shadow). It was also observed that shadows were followed by regions of higher (increasing radial derivative (elevated region beyond the shadow). We also observed regions of negative radial derivative before shadows and regions of positive radial derivatives after shadows.
4. For uniform, but high intensity regions (non-shadows) we observed regions of positive radial derivatives before them and regions of negative radial derivative after them. Of course, these uniform intensity areas themselves have low radial derivative like shadows. Thus the signs of radial derivative before and after a region of low radial derivative may be useful in distinguishing shadows from other low derivative regions.
5. However, we found some exceptions to these observations also. Radial derivative seems to be the most promising of all the preprocessing techniques test by us for detection and identifying shadows.

However, in order to put confidence into the use of radial derivative for detection and identification of shadows, more testing with data with a corresponding topographical map is

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necessary. We did not have the topographical map to verify our conclusions. Also, the radial derivative makes use of radial changes and it does not take into account of side-to-side changes. Using both radial and local derivatives may improve the decision making.

Originally we plotted the radial derivative information on a seven point grey scale. However this plot looked too cluttered with symbols. Hence to have a clearer picture we replotted the radial derivatives on a five level grey scale. The derivative values represented by +, blank, and - were replaced by blanks. This plot is shown for the upper quadrant in Figure 4.7. The regions of low intensity depicted in Figure 2.20 are shown dotted in Figure 4.7. Using the plot we examined the regions of high but relatively constant intensity preceeding shadows to test them as precursors of shadows. We noticed that for these regions of high but constant intensity before shadows there were regions of positive derivative before them and regions of negative derivatives after them. This indicated that these regions are some sort of precursors of shadows. (These areas were selected by hand. This selection may be done by a computer program. However these programs may be quite expensive and it is easier to select them by the sight.) Figure 4.8 shows the same information as Figure 4.7, but with the precursors indicated by numbers 0-9 and letters

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B-U.

Then we tried to distinguish these groups of bright regions to see if these belong to more than one type of regions. Our investigation did not bring out any significant differences among the various groups.

Next we attempted to correlate these precursor regions to the shadows. We did observe that there were shadows following many of these precursors. This gave confidence to our conclusions.

Finally, we used the spanning tree algorithm to cluster the dark areas (possible shadows). We did not obtain any accurate division of these areas into individual shadows.

For a 128×128 point picture it took 26 seconds of CPU time to calculate the radial derivatives. Storage requirement was 2×128^2 bytes. We were allotted 200 kilobytes and it was sufficient. Expense was \$1.95 per run.

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4.5 Conclusions

Out of the three techniques of preprocessing used, the radial derivative technique seems to be the most promising for detection and identification of shadows. However, combinations of these techniques may prove to be more useful under some conditions. It is necessary to have a topographical map corresponding to the data used to verify our conclusions.

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4.6 Note

We, at Clarkson, wrote, debugged and tested the programs used for the grey-scale plots, calculation of local variances, local gradient and radial derivatives. These programs are specifically written for these types of data (type of numbers, data x-y, rather than radial format). These programs are now available on disk and also on tapes for further use on this type of project.

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5.0 CONCLUSIONS

This report has presented the results of a comparison of nonparametric clustering techniques and their use in examining radar clutter from shadowed terrain. Successful techniques for extracting features from clutter will aid in understanding the underlying structure of the clutter and in turn will lead to the development of useful clutter models. The Forgy-Jancey and minimum spanning tree algorithms were tested on both simulated and actual radar data. Some preprocessing techniques were also tested on the actual radar data in connection with the minimum spanning tree algorithm. The Forgy-Jancey algorithm was found to be a very flexible tool, handling large multidimensional data sets with minimal cost in CPU time and storage. Unfortunately the performance of this algorithm was found to be inconsistent in terms of finding the "natural" number of clusters. In general, repeated applications of this algorithm are necessary in order to find the optimum number of clusters and parameter values. A more detailed discussion of the conclusions pertaining to the Forgy-Jancey algorithm can be found in Section 2.5.

The minimum spanning tree algorithm was found to be more robust in its ability to detect a natural clustering; it was

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never observed to split a natural cluster as was the Forgy-Jancey algorithm. The ARTHUR implementation of the minimum spanning tree provides flexibility in clustering, since once the tree is found, the data can be clustered repeatedly without recomputing the tree. Finding the tree, however, turned out to be costly for large data sets, since the ARTHUR implementation requires calculation and storage of the distance between every pair of data entities. Alternative procedures for computing the tree are available, however, as are alternative procedures for clustering the data from the tree. A detailed discussion is presented in Section 3.5.

A discussion of the preprocessing techniques examined is presented in Section 4, with the conclusions in Section 4.5. The preprocessing was motivated by the need to reduce the amount of data provided to the minimum spanning tree algorithm, but was found to be a useful technique in its own right for extracting features from clutter. Computation of the radial derivative was the most revealing of the techniques studied for locating and defining the edges of shadows.

Clustering techniques appear to hold great promise for examination of the structure of clutter returns, provided that the techniques are applied with some care and common sense. A primary result of the work to date has been installation of the relevant programs on the Clarkson College computer, and the

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familiarization of the researchers with their use. The next step would be a detailed application of these programs to actual radar data, including an examination of a wider variety of clutter properties.

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APPENDIX: PROGRAM LISTINGS

This appendix contains the listings of the programs developed and used in this project. Figure A.1 is the comments section from subroutine EXEC, and describes the input format for Forgy-Jancey data. Figure A.2 is the input specification for the outlier Forgy-Jancey subroutine EXEC3. Figure A.3 is the subroutine EXEC to go along with the comments in Figure A.1. Figure A.4 is subroutine EXEC2 which allows outputting of the sorted data. Figure A.5 is subroutine EXEC3, the outlier calling subroutine. Figure A.6 (Parts 1-3) is subroutine KMEAN, the original Forgy-Jancey clustering routine. Figure A.7 (Parts 1-3) is outlier subroutine KMEAN2. Figure A.8 is the RESULT subroutine, which outputs the results of KMEAN. Figure A.9 is subroutine RESULT2, which allows output of the sorted data array. Figure A.10 shows the driver routine MAIN, function DIST, and subroutines USER and USROUT for a sample Forgy-Jancey clustering run. Figure A.11 shows MAIN and DIST for a sample outlier run, and also another version of DIST used in intensity clustering. Figure A.12 is subroutine RAY, our rayleigh random number generator. Figure A.13 is the program that created the rayleigh data set with $\sigma = 10,000$. Figure A.14 is the program that created the rayleigh data set with $\sigma = 50$. Figure A.15 is the plotting program that produced

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all of our 100 x 100 and 128 x 128 point cluster plots. Figure A.16 is the grey scale plotting program used to generate all grey scale plots without overprinting. These programs were all either written at Clarkson, or installed and modified at Clarkson to suit the purposes of the project. For a description of ARTHUR, see Section 3, and the ARTHUR program documentation [7].

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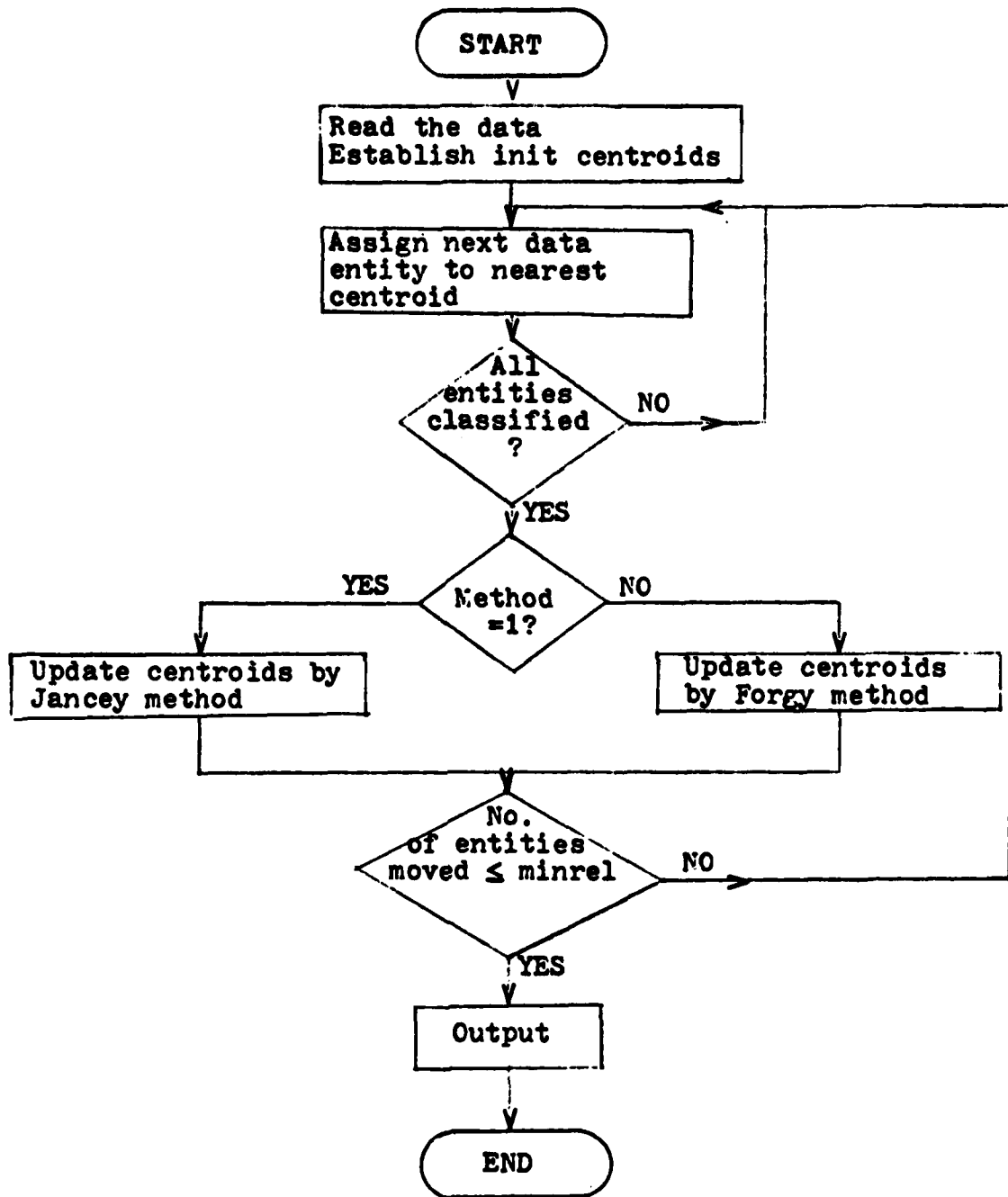


Figure 2.1: The Forgy-Jancey Algorithm

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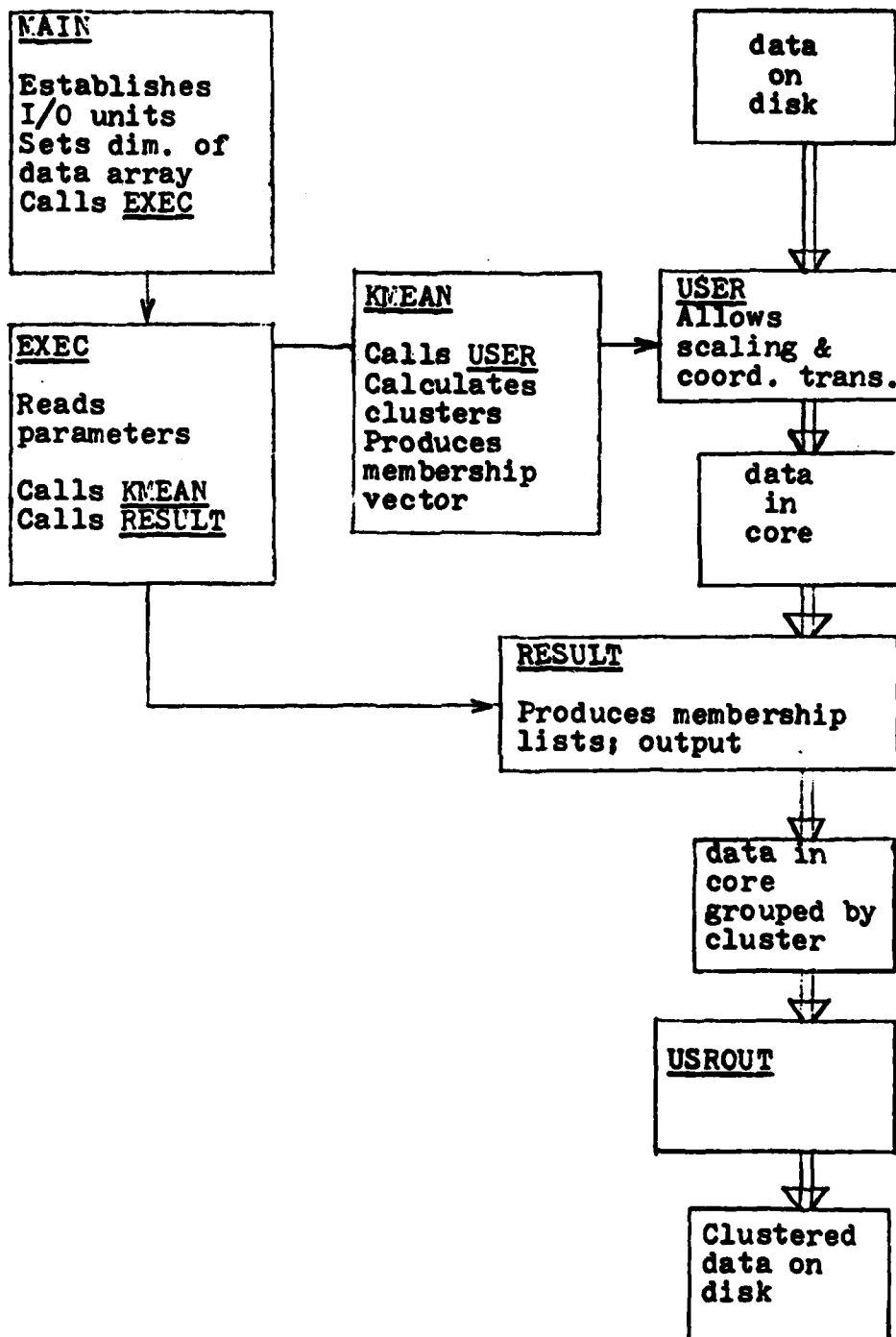


Figure 2.2: Forgy-Jancey Program Path

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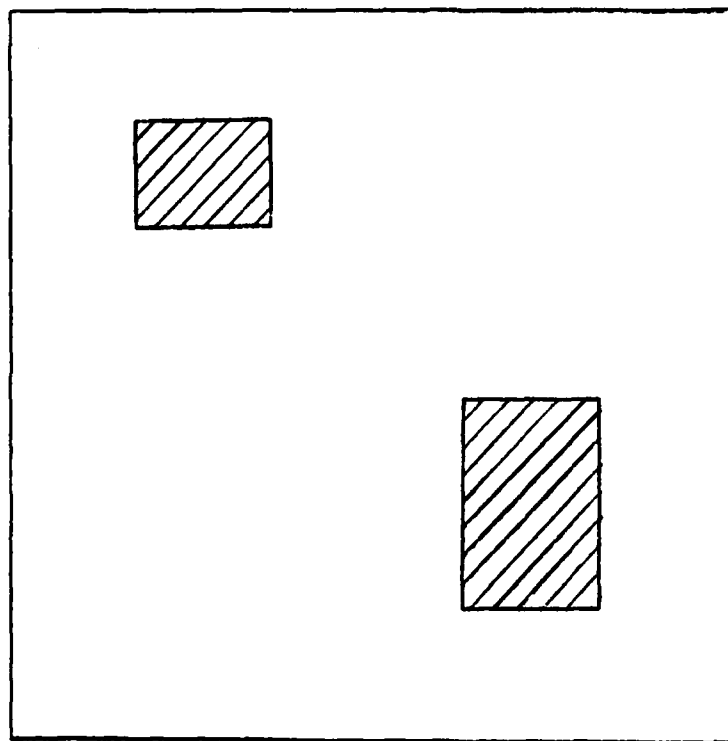


Figure 2.3: Test Scene for Clustering

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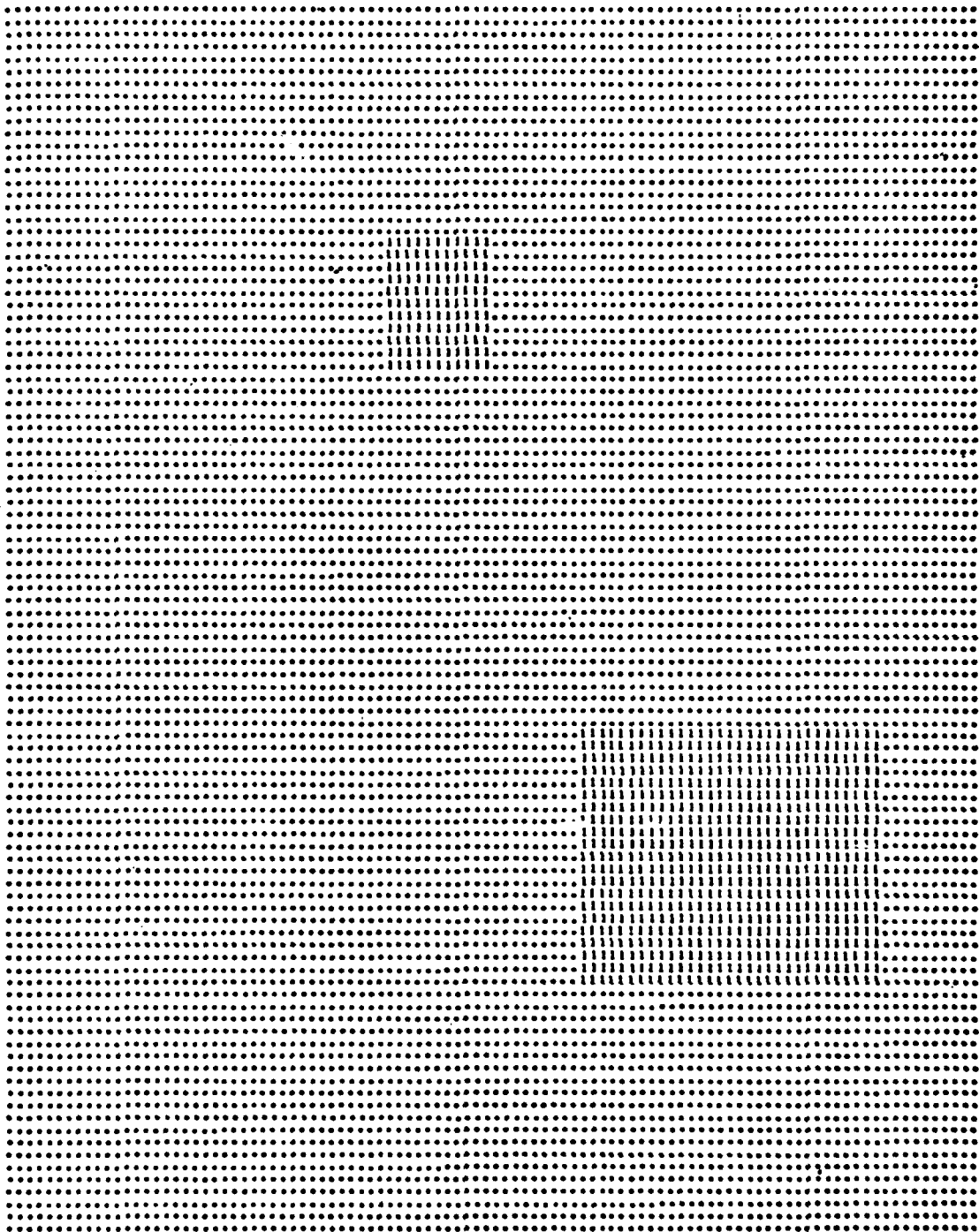


Figure 2.4: Intensity Clustering of Test Scene

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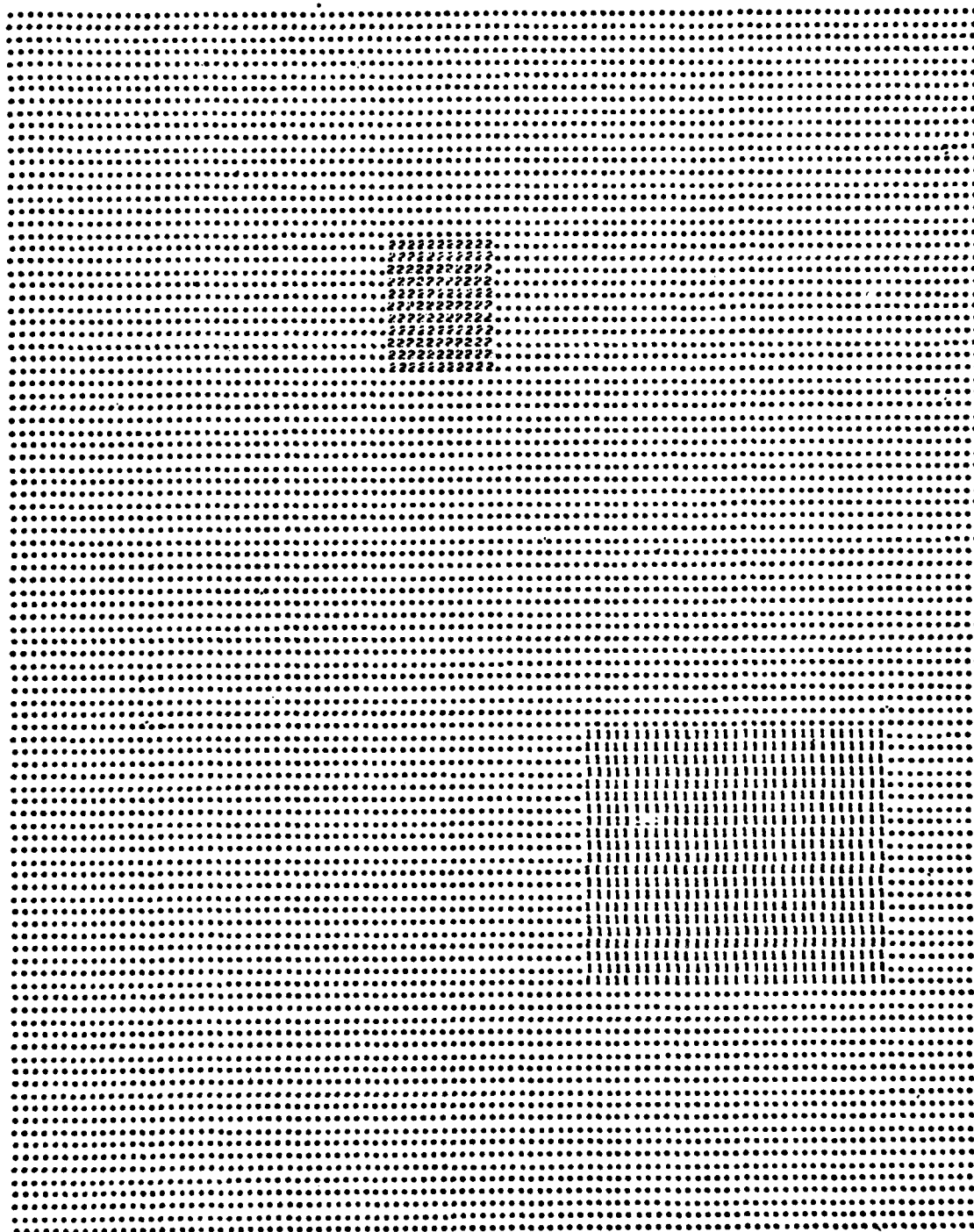


Figure 2.5: x-y Clustering of Test Scene

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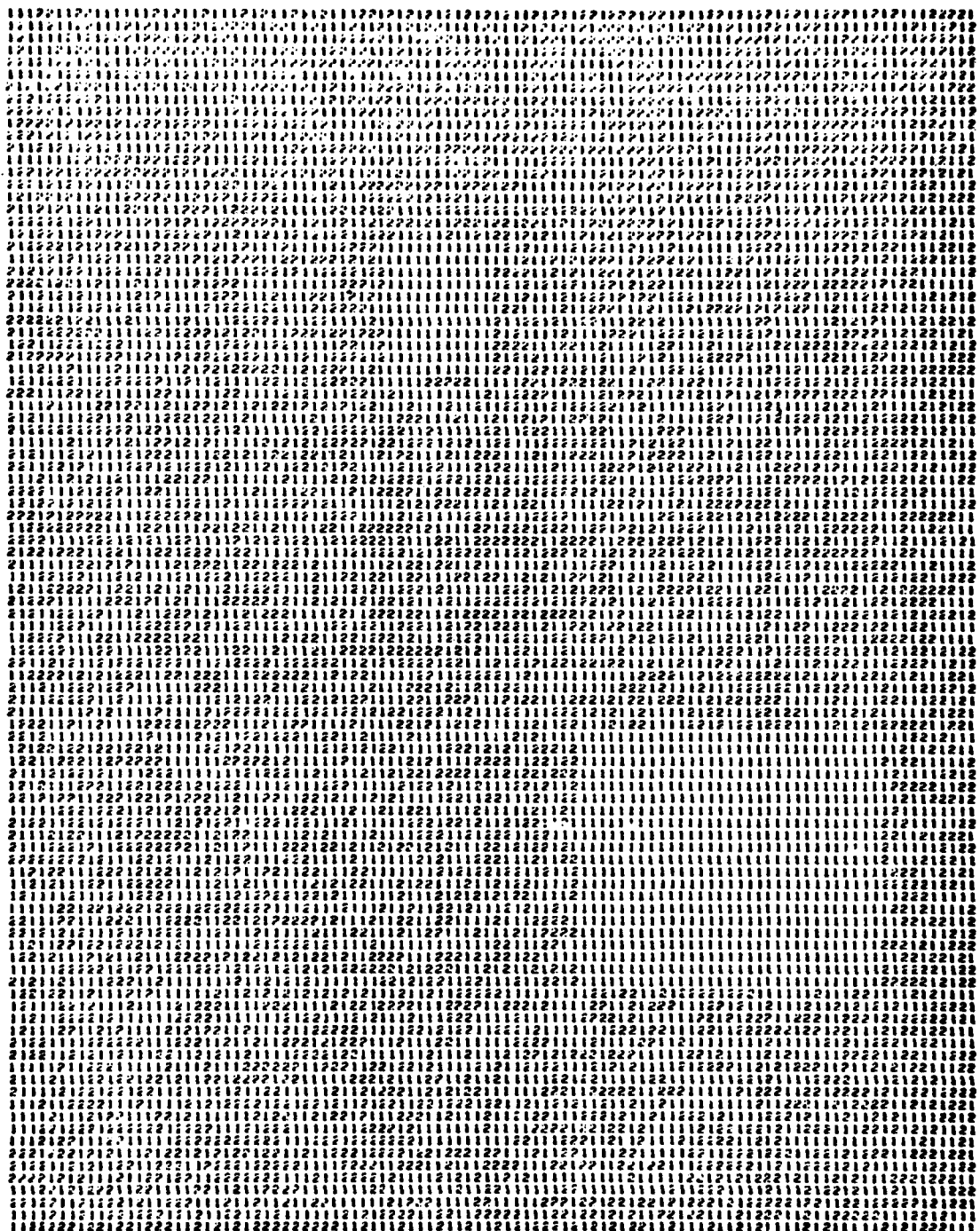


Figure 2.6: Intensity Clustering of Simulated Shadows

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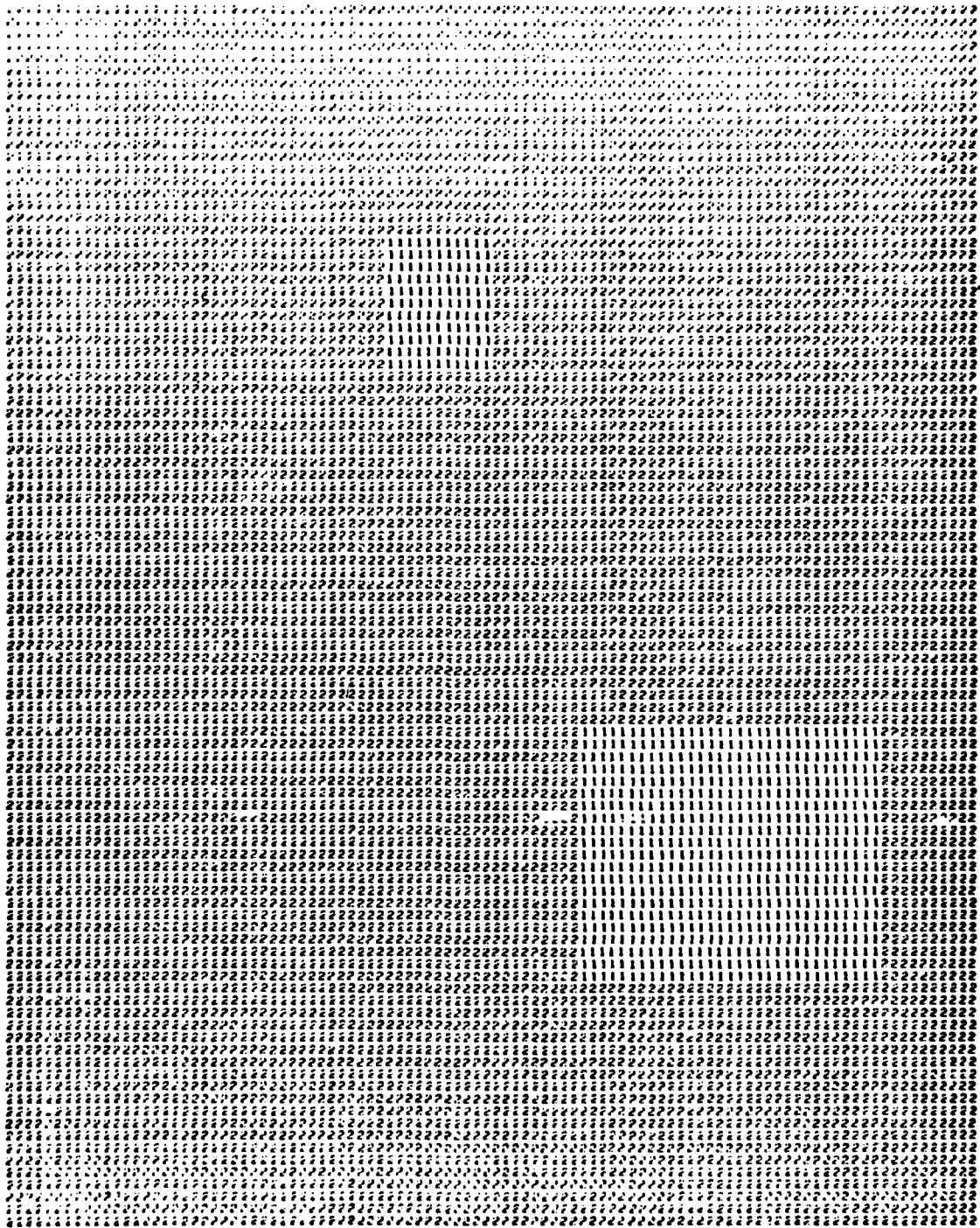


Figure 2.7: Intensity Clustering; Intensity in dB

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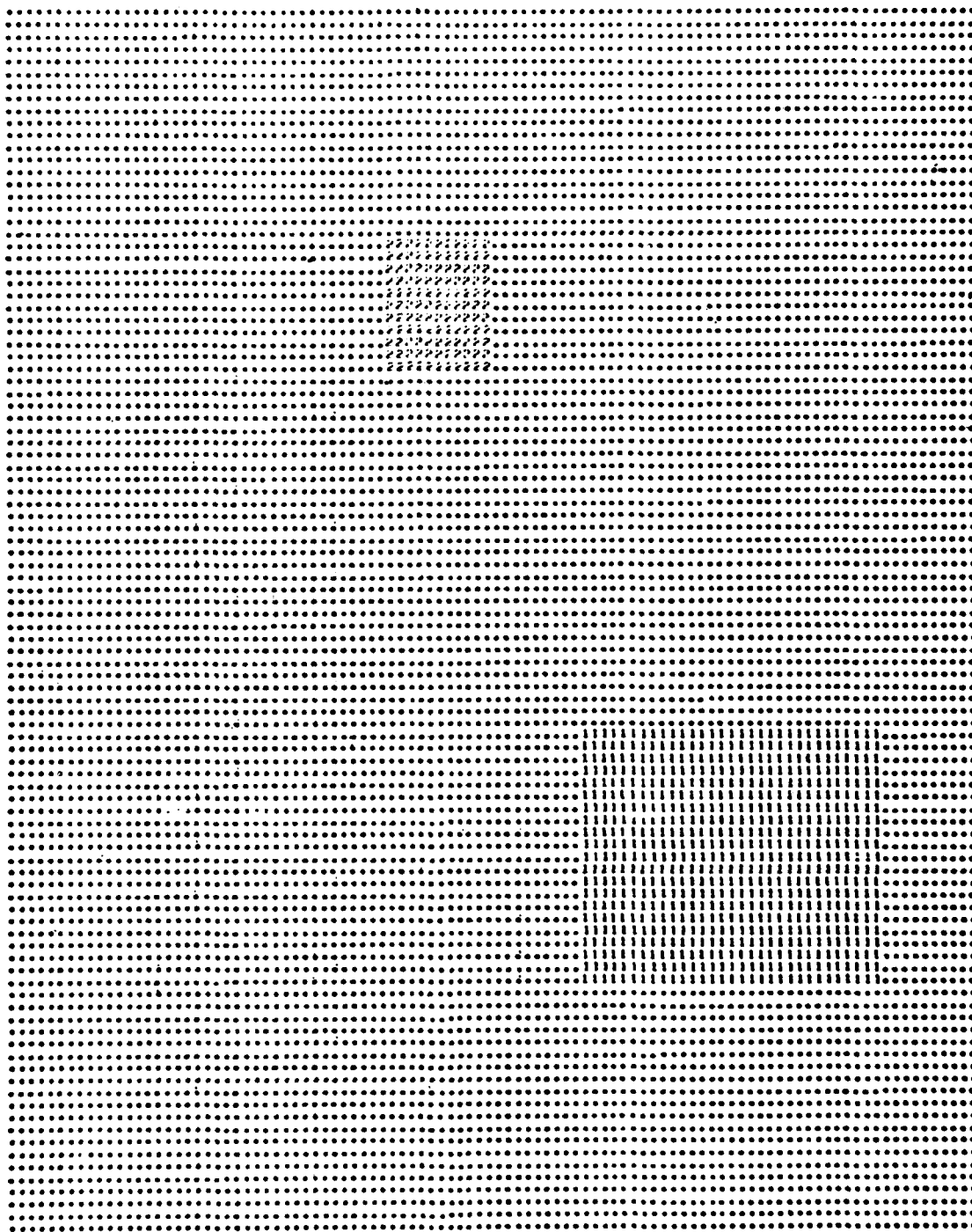


Figure 2.8: x-y Clustering of Simulated Shadows

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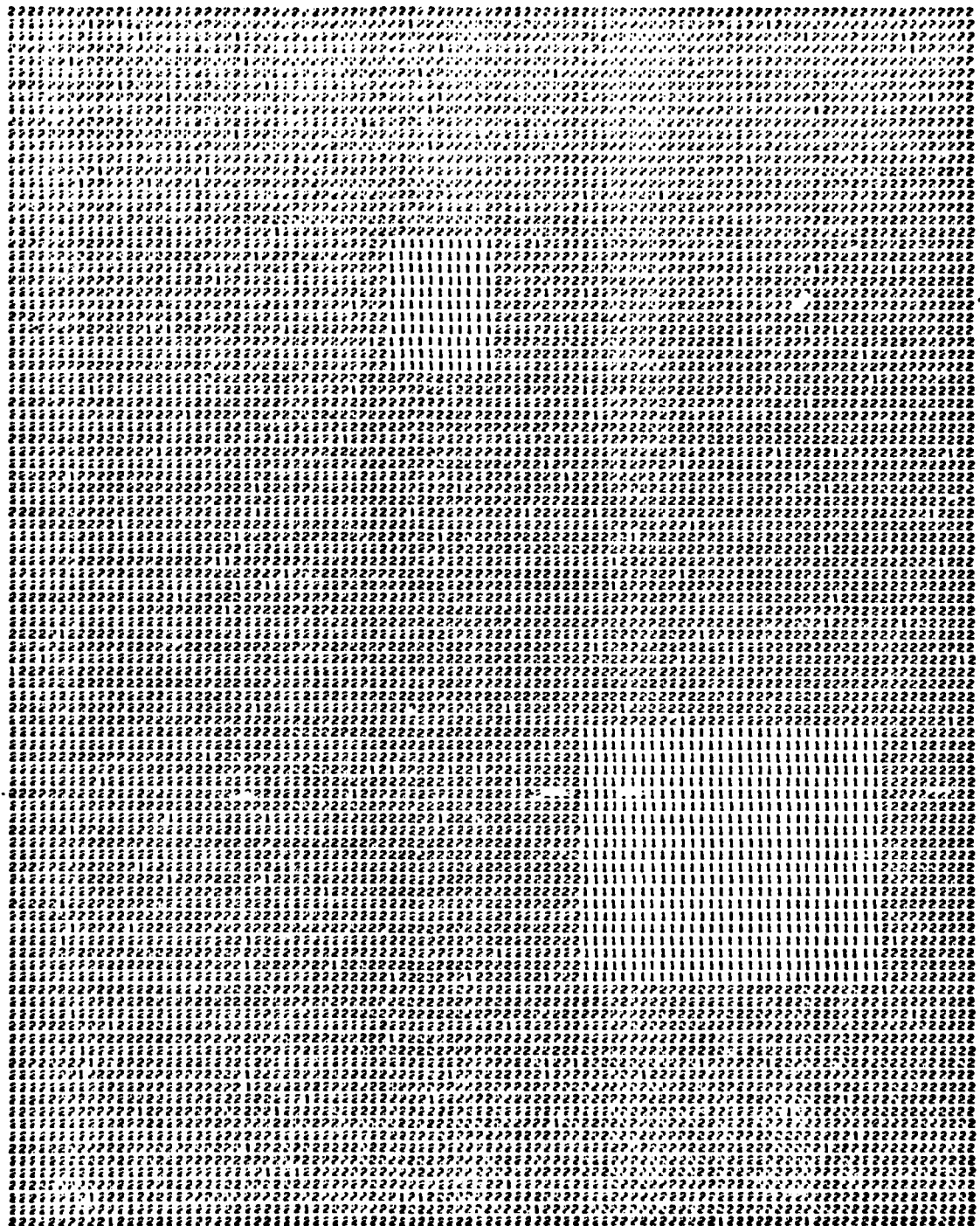


Figure 2.9: Intensity Clustering; Low Background Level

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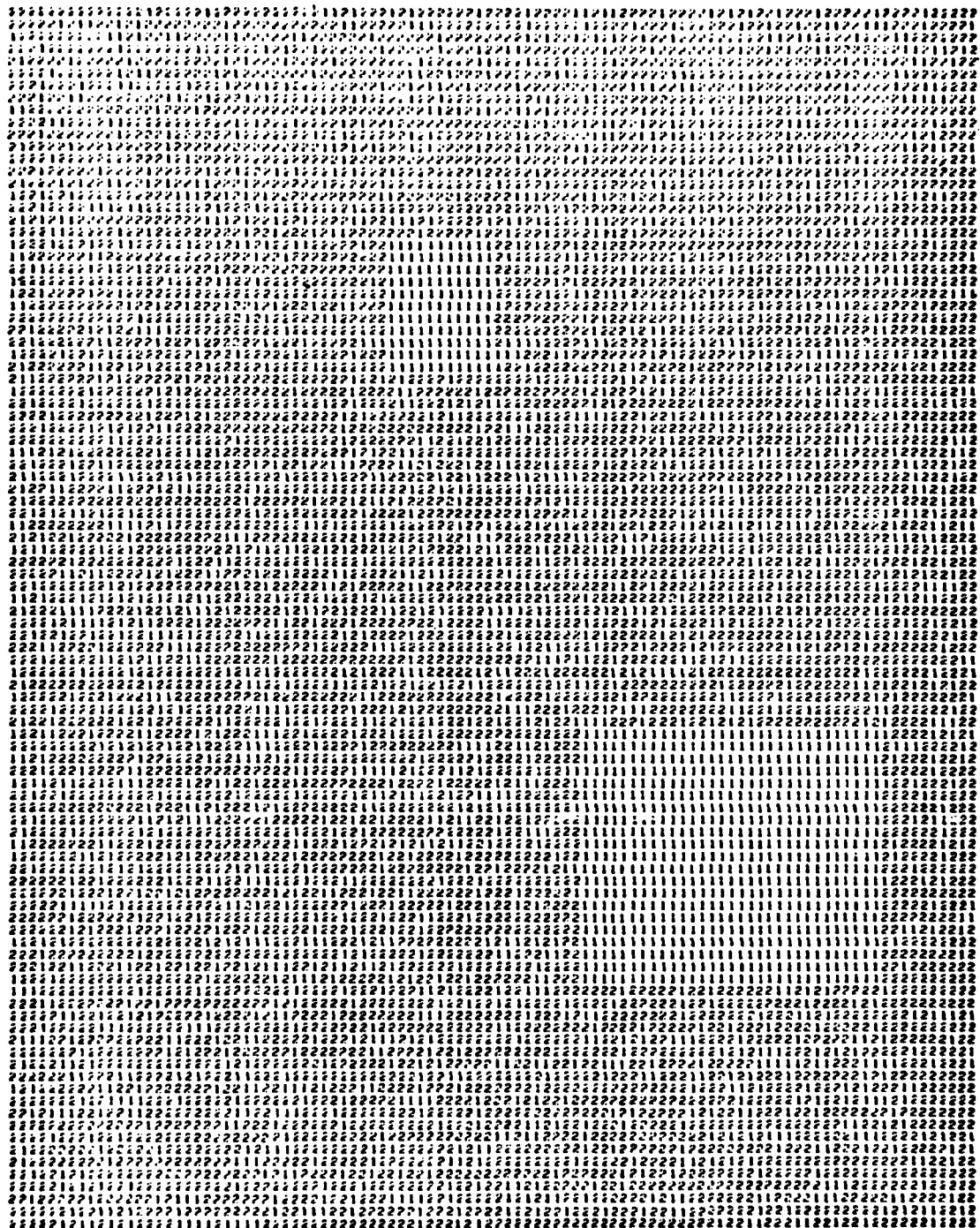


Figure 2.10: Low Background Level Run to Convergence

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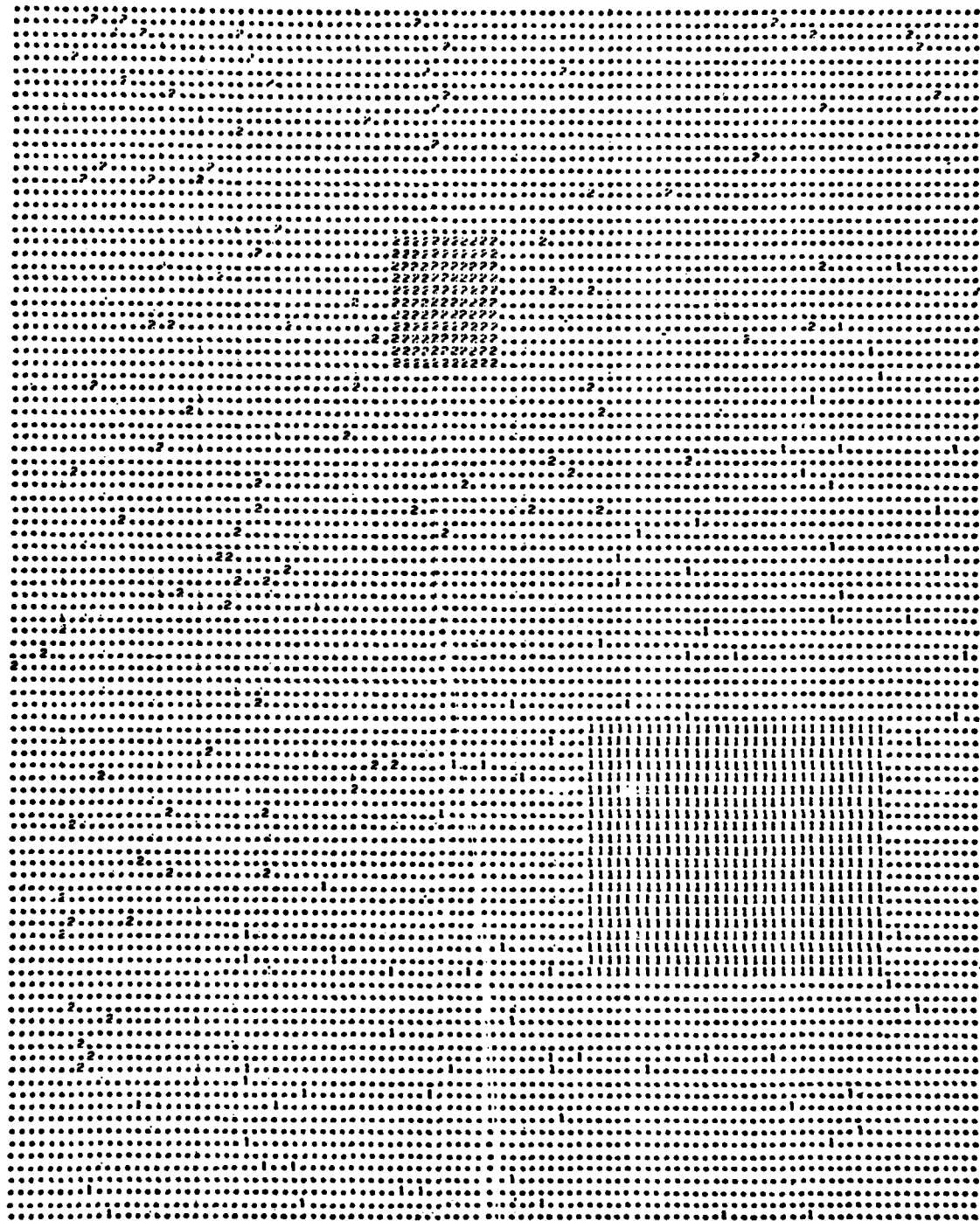


Figure 2.11: x-y Clustering,, Low Background Level; NC=2

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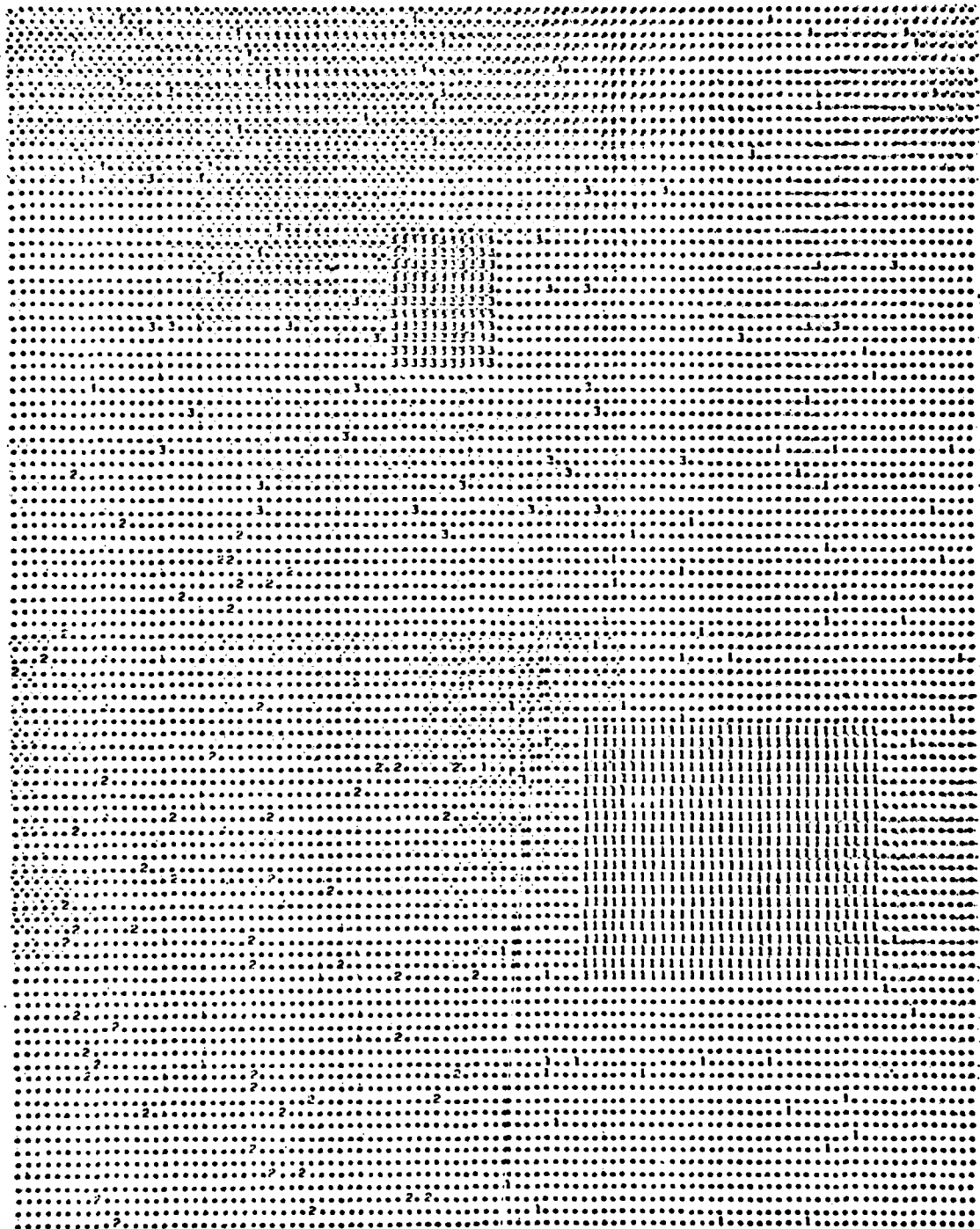


Figure 2.12: x-y Clustering, Low Background Level; NC=3

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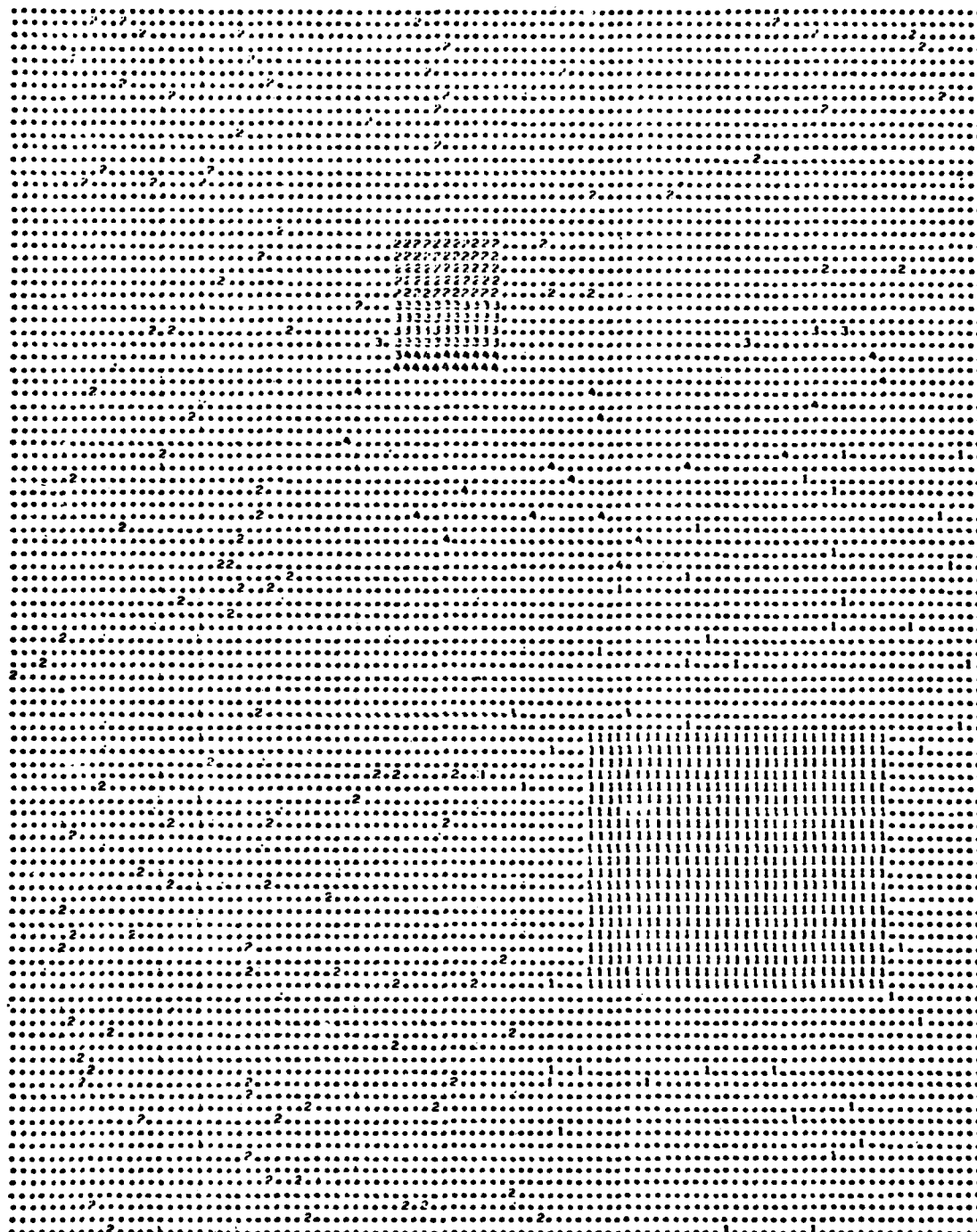


Figure 2.13: x-y Clustering, Low Background Level; NC=4

MODELING OF SHADOWS IN RADAR CLUTTER

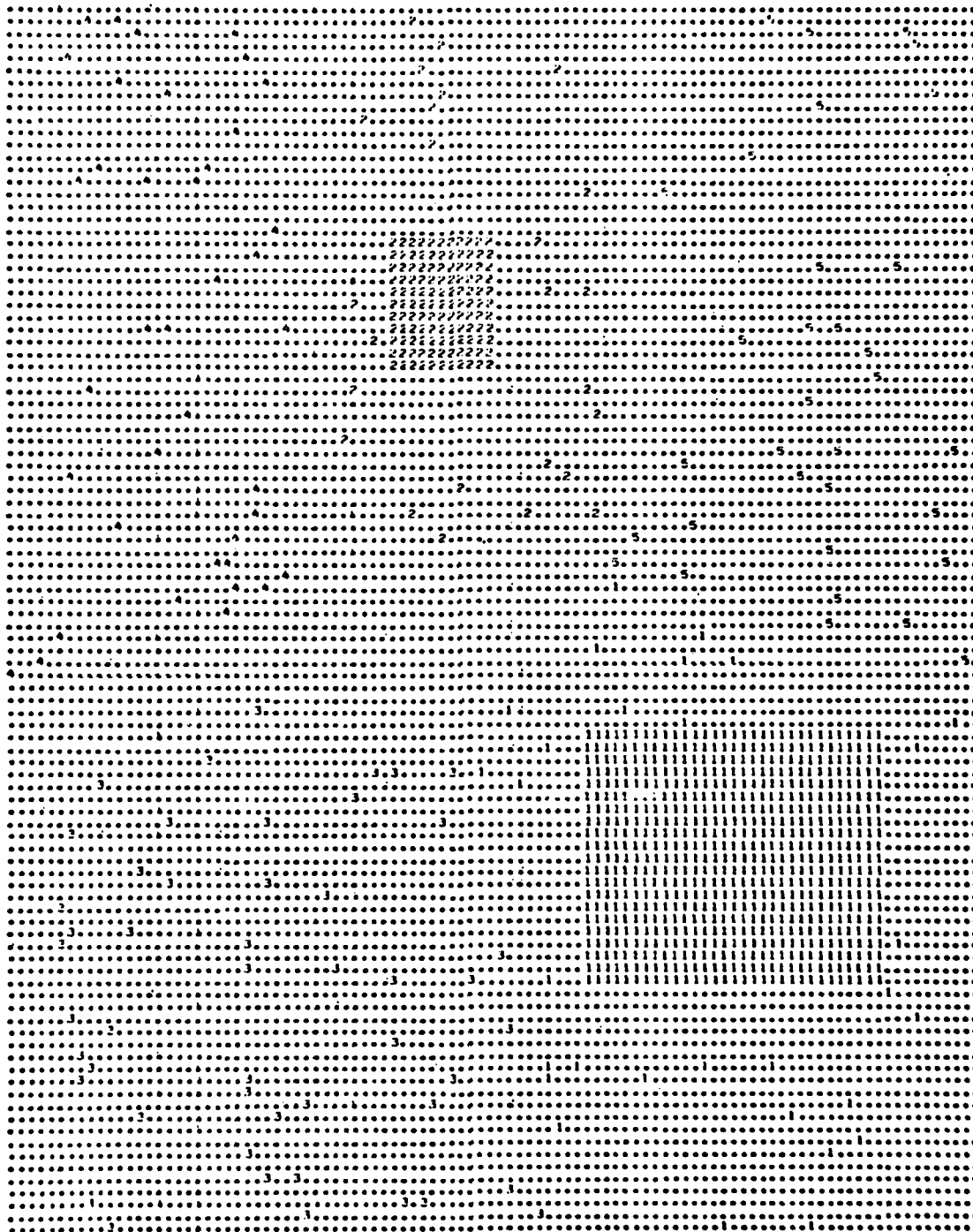


Figure 2.14: x-y Clustering, Low Background Level; NC=5

63

MODELING OF SHADOWS IN RADAR CLUTTER

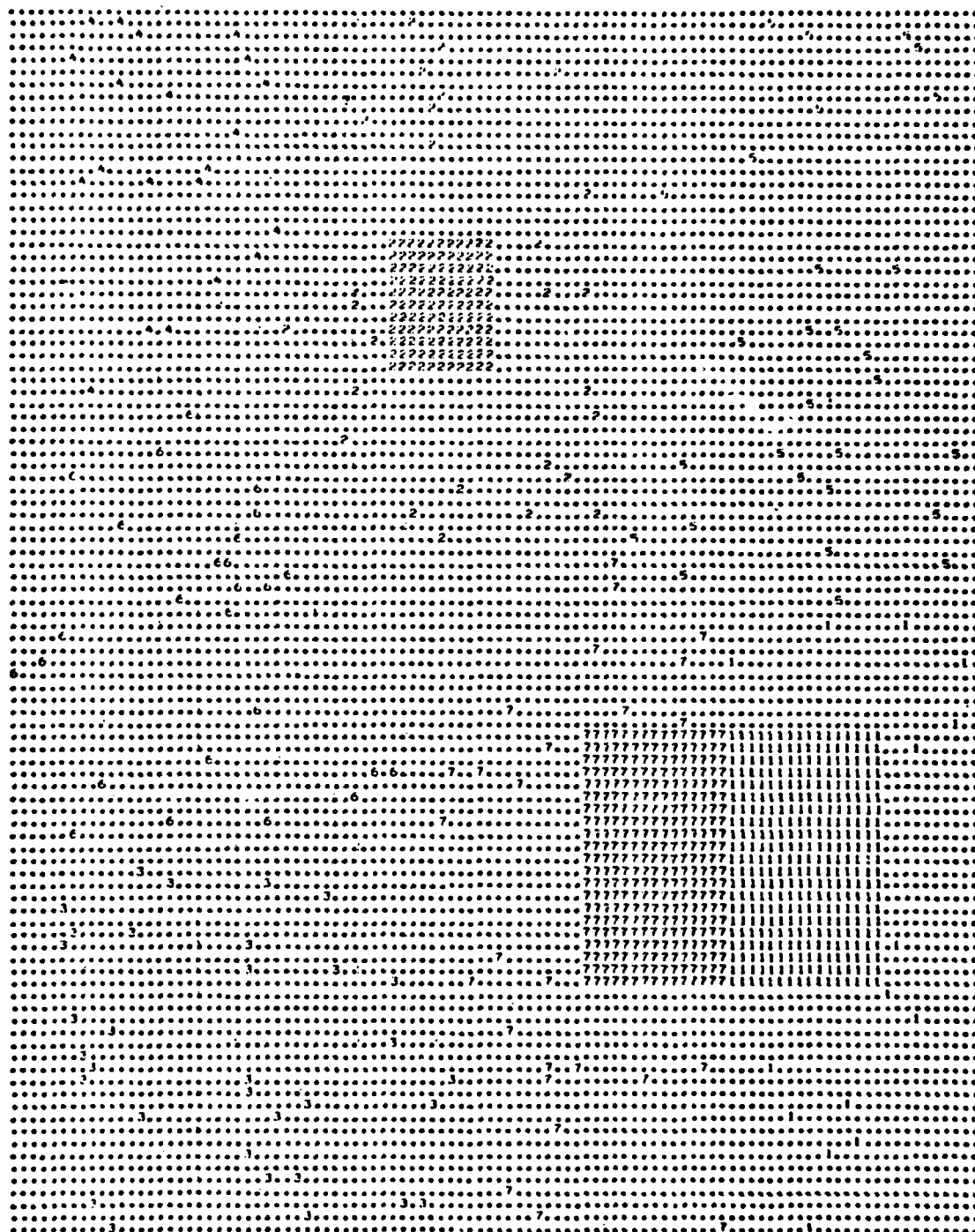


Figure 2.16: x-y Clustering, Low Background Level; NC=7

MODELING OF SHADOWS IN RADAR CLUTTER

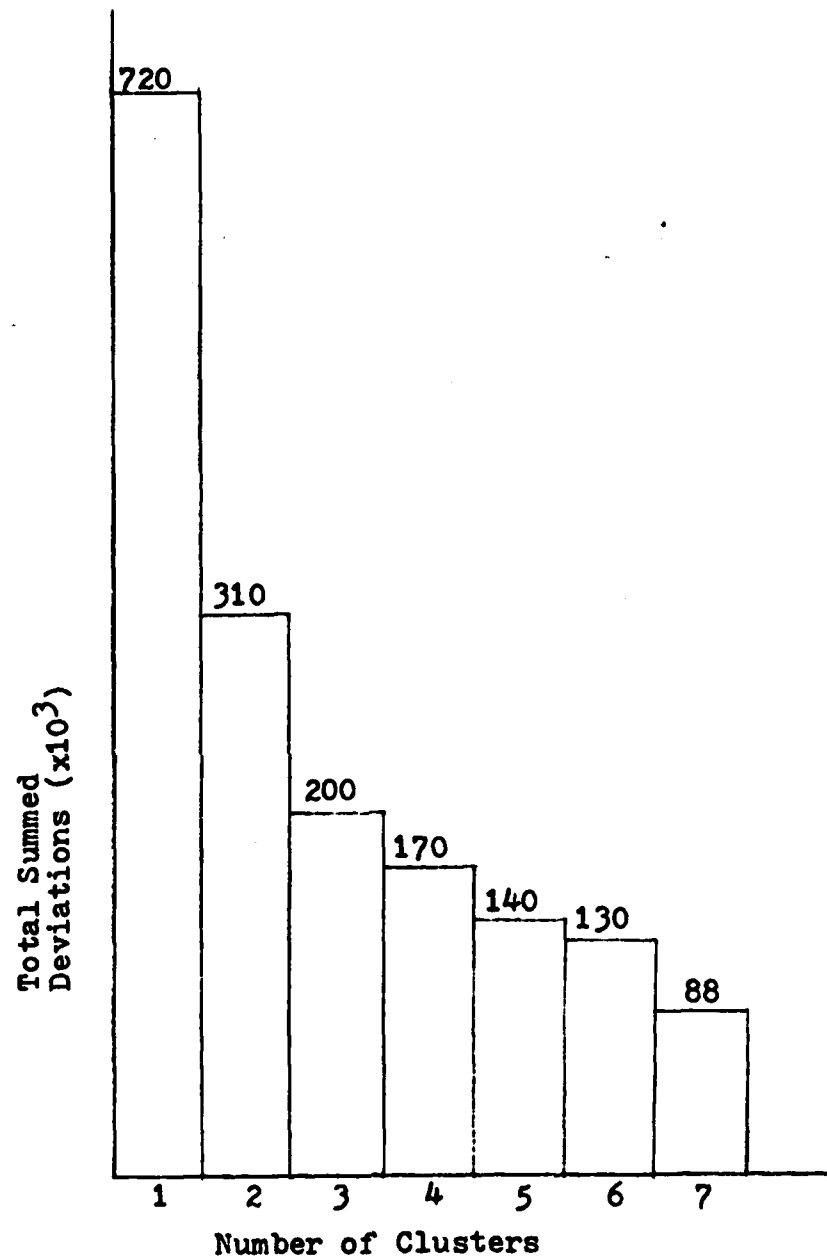


Figure 2.17: Total Summed Deviations

MODELING OF SHADOWS IN RADAR CLUTTER

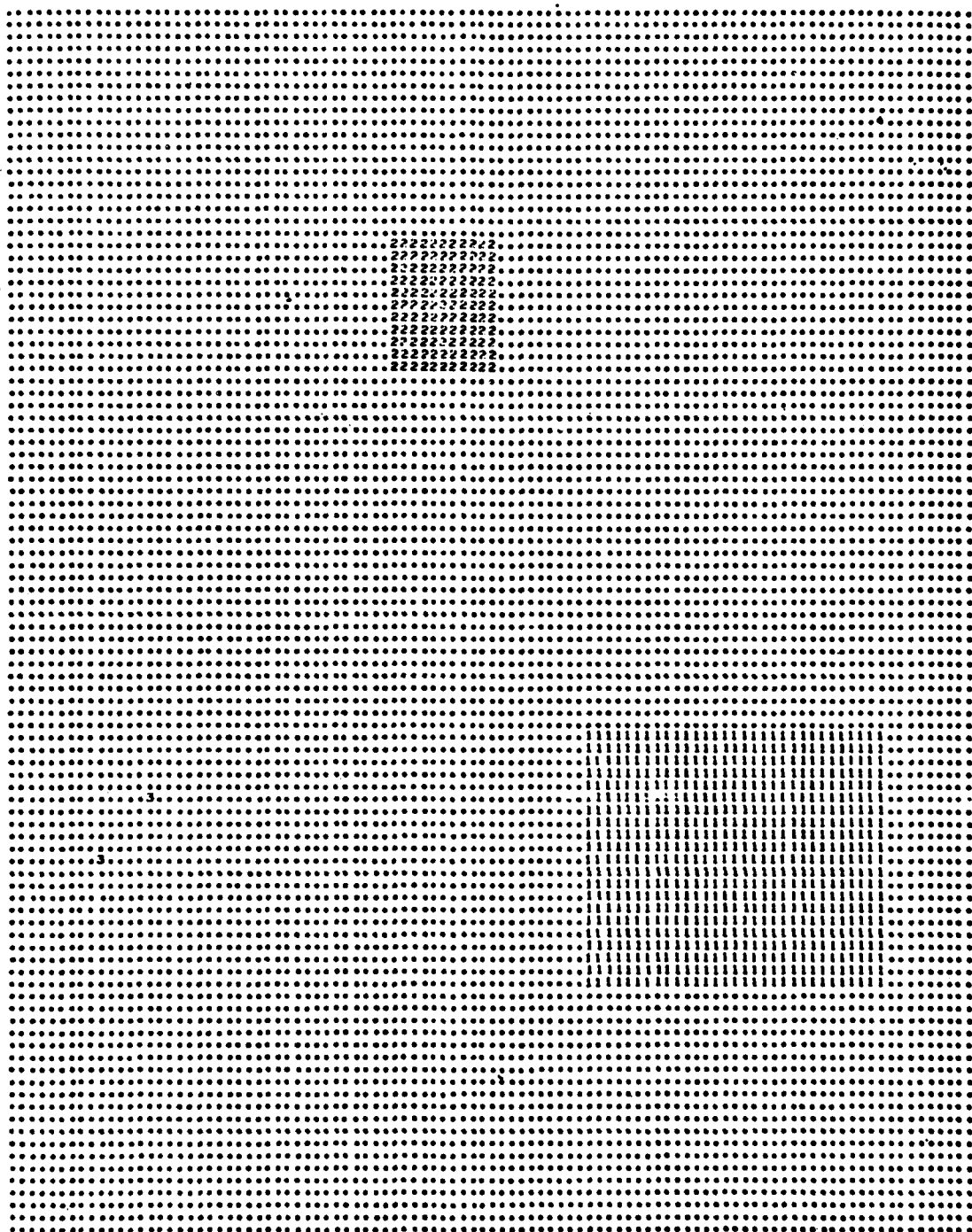


Figure 2.18: Test Scene With Outliers

MODELING OF SHADOWS IN RADAR CLUTTER



Figure 2.19: Radar Data

MODELING OF SHADOWS IN RADAR CLUTTER

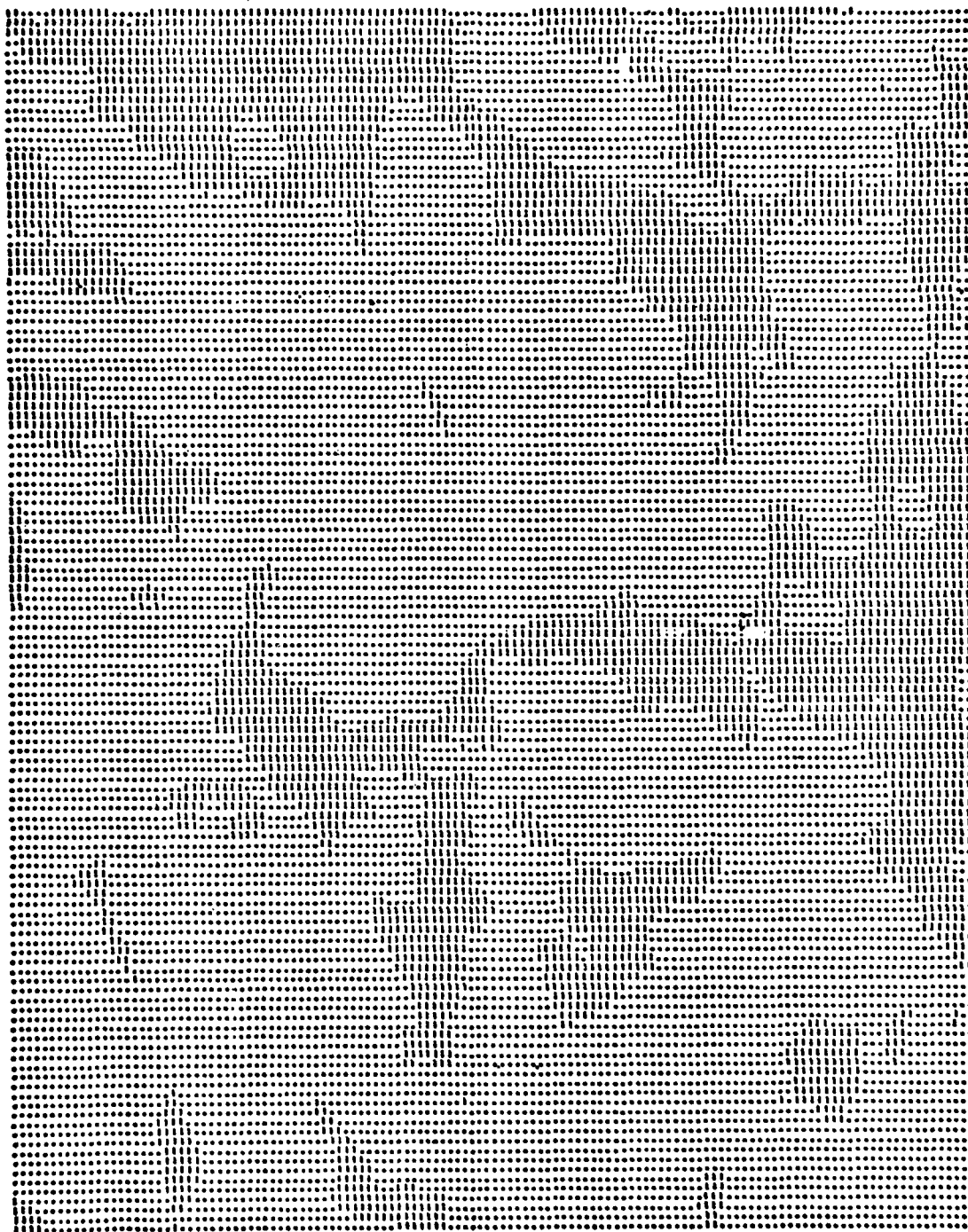


Figure 2.20: Low Intensity Regions

MODELING OF SHADOWS IN RADAR CLUTTER



Figure 2.21: x-y Clustering of Low Intensity Regions

MODELING OF SHADOWS IN RADAR CLUTTER

161	0	10.	44.	0.0	162	0	12.	45.	0.0	163	0	10.	46.	0.0	164	0	12.	47.	0.0
165	0	10.	48.	0.0	166	0	12.	49.	0.0	167	0	10.	50.	0.0	168	0	12.	51.	0.0
169	0	10.	52.	0.0	170	0	12.	53.	0.0	171	0	10.	54.	0.0	172	0	12.	55.	0.0
173	0	10.	56.	0.0	174	0	12.	57.	0.0	175	0	10.	58.	0.0	176	0	12.	59.	0.0
177	0	10.	60.	0.0	178	0	12.	61.	0.0	179	0	10.	62.	0.0	180	0	12.	63.	0.0
181	0	10.	64.	0.0	182	0	12.	65.	0.0	183	0	10.	66.	0.0	184	0	12.	67.	0.0
185	0	10.	68.	0.0	186	0	12.	69.	0.0	187	0	10.	70.	0.0	188	0	12.	71.	0.0
189	0	10.	72.	0.0	190	0	12.	73.	0.0	191	0	10.	74.	0.0	192	0	12.	75.	0.0
193	0	10.	76.	0.0	194	0	12.	77.	0.0	195	0	10.	78.	0.0	196	0	12.	79.	0.0
197	0	10.	80.	0.0	198	0	12.	81.	0.0	199	0	10.	82.	0.0	200	0	12.	83.	0.0
201	0	10.	84.	0.0	202	0	12.	85.	0.0	203	0	10.	86.	0.0	204	0	12.	87.	0.0
205	0	10.	88.	0.0	206	0	12.	89.	0.0	207	0	10.	90.	0.0	208	0	12.	91.	0.0
209	0	10.	92.	0.0	210	0	12.	93.	0.0	211	0	10.	94.	0.0	212	0	12.	95.	0.0
213	0	10.	96.	0.0	214	0	12.	97.	0.0	215	0	10.	98.	0.0	216	0	12.	99.	0.0

X-Y RAYLEIGH DATA

1-4 DIST. WHEN I GET THROUGH WITH IT, YOUR DATA IS GONNA BE WAYYYY OUT.

NIN 30 CREATED IN INPU NPAT 210 NTEST 0 NVAR 2 NCAT 1 IFER 0

ROUT 30

NTYPE 0 MANALYSE THE DISTANCE OF CPTER (2)
(IF, EUCLIDEAN DISTANCE...)

X-Y RAYLEIGH DATA

1-4 THREE. I REALLY PUT YOUR DATA OUT ON A LINE.

NIN 30 CREATED IN DIST NPAT 210 NTEST 0 NVAR 2 NCAT 1 IFER 0

ROUT 30

NIT 1 PRUNING PARAMETERS WILL BE READ FROM CARDS.

***** NODE *****				***** NEIGHBORS *****				DISTANCE	
1	0	2.	9.	0.0	2	0	2. 12.	0.0	3.000E 00
					11	0	5. 7.	0.0	3.606E 00
2	0	2.	12.	0.0	5	0	3. 14.	0.0	2.236E 00
					1	0	2. 9.	0.0	3.000E 00
3	0	2.	42.	0.0	9	0	4. 45.	0.0	3.606E 00
4	0	2.	79.	0.0	7	0	3. 83.	0.0	4.123E 00
5	0	2.	14.	0.0	15	0	7. 12.	0.0	4.472E 00
					2	0	2. 12.	0.0	2.236E 00
6	0	3.	24.	0.0	12	0	5. 25.	0.0	2.236E 00
7	0	1.	23.	0.0	21	0	9. 84.	0.0	6.093E 00
					4	0	2. 74.	0.0	4.123E 00
					8	0	3. 93.	0.0	1.000E 01
8	0	3.	53.	0.0	7	0	3. 83.	0.0	1.000E 01
					10	0	4. 44.	0.0	1.414E 00

Figure 3.1: TREE Example Run

MODELING OF SHADOWS IN RADAR CLUTTER

THE DATA WAS THEN CLUSTERED SEARCHING TO A DEPTH OF 2
 INCLUDING POINTS HAVE BEEN DESIGNATED BY A FACTOR OF 2.0000E 00
 AND A WEIGHT OF 0.0 STANDARD DEVIATIONS.

5 CLUSTERS DETECTED

CLUSTER 1 CONSISTS OF THE FOLLOWING 207 PATTERNS.

1	0	2. 12.	0.0
2	0	2. 12.	0.0
11	0	3. 14.	0.0
15	0	3. 14.	0.0
16	0	7. 12.	0.0
17	0	4. 17.	0.0
27	0	18. 21.	0.0
30	0	15. 23.	0.0
73	0	11. 25.	0.0
70	0	23. 22.	0.0
29	0	15. 15.	0.0
16	0	7. 27.	0.0
119	0	27. 17.	0.0
86	0	21. 26.	0.0
26	0	14. 10.	0.0
12	0	34. 25.	0.0
171	0	34. 15.	0.0
114	0	27. 15.	0.0
33	0	12. 28.	0.0
120	0	27. 29.	0.0
28	0	15. 8.	0.0
6	0	3. 24.	0.0
174	0	17. 16.	0.0
95	0	25. 36.	0.0
125	0	43. 12.	0.0
133	0	28. 38.	0.0
153	0	49. 18.	0.0
177	0	39. 7.	0.0
134	0	28. 40.	0.0
169	0	32. 36.	0.0
138	0	46. 22.	0.0
168	0	32. 9.	0.0
146	0	25. 40.	0.0
135	0	28. 41.	0.0
121	0	27. 40.	0.0
173	0	36. 35.	0.0
109	0	46. 23.	0.0
157	0	30. 40.	0.0
147	0	27. 41.	0.0
122	0	27. 41.	0.0
187	0	26. 43.	0.0
171	0	48. 24.	0.0
184	0	44. 24.	0.0
158	0	39. 41.	0.0
108	0	28. 41.	0.0
96	0	25. 40.	0.0
194	0	50. 23.	0.0
102	0	48. 27.	0.0
181	0	42. 26.	0.0
159	0	30. 42.	0.0
67	0	25. 41.	0.0
82	0	21. 40.	0.0
168	0	38. 26.	0.0
198	0	47. 29.	0.0
175	0	40. 26.	0.0

Figure 3.2: Default Clustering

MODELING OF SHADOWS IN RADAR CLUTTER

THE DATA HAS BEEN GENERATED BY A COMPUTER. THE
INDEPENDENT VARIABLES HAVE BEEN GENERATED BY A GAUSSIAN OF 1.00000E-06
AND A STANDARD OF 1.00000E-06 STANDARD DEVIATIONS.

32 CLUSTERS DETECTED

CLUSTER	1	CONSISTS OF THE FOLLOWING	5 PATTERNS.
1	0	20. 90.	0.0
2	0	20. 120.	0.0
3	0	30. 140.	0.0
15	0	70. 120.	0.0
17	0	80. 170.	0.0
CLUSTER	2	CONSISTS OF THE FOLLOWING	4 PATTERNS.
27	0	140. 210.	0.0
30	0	150. 200.	0.0
23	0	110. 240.	0.0
20	0	150. 150.	0.0
CLUSTER	3	CONSISTS OF THE FOLLOWING	2 PATTERNS.
26	0	140. 130.	0.0
29	0	150. 80.	0.0
CLUSTER	4	CONSISTS OF THE FOLLOWING	3 PATTERNS.
16	0	70. 270.	0.0
12	0	50. 250.	0.0
6	0	30. 240.	0.0
CLUSTER	5	CONSISTS OF THE FOLLOWING	5 PATTERNS.
70	0	230. 220.	0.0
119	0	270. 170.	0.0
46	0	210. 260.	0.0
118	0	270. 150.	0.0
33	0	190. 260.	0.0
CLUSTER	6	CONSISTS OF THE FOLLOWING	1 PATTERNS.
120	0	270. 240.	0.0
CLUSTER	7	CONSISTS OF THE FOLLOWING	132 PATTERNS.
95	0	250. 360.	0.0
133	0	230. 360.	0.0
134	0	280. 400.	0.0
146	0	290. 400.	0.0
135	0	230. 410.	0.0
121	0	270. 400.	0.0
157	0	300. 400.	0.0
147	0	290. 410.	0.0
122	0	270. 410.	0.0
107	0	260. 400.	0.0
158	0	300. 410.	0.0
109	0	260. 410.	0.0
96	0	250. 420.	0.0
159	0	300. 420.	0.0
97	0	250. 410.	0.0
82	0	240. 400.	0.0
160	0	300. 430.	0.0
148	0	290. 420.	0.0
82	0	240. 410.	0.0
71	0	230. 400.	0.0
161	0	300. 440.	0.0
149	0	290. 430.	0.0
136	0	280. 420.	0.0

Figure 3.3: Better Clustering

MODELING OF SHADOWS IN RADAR CLUTTER

THE TREE HAS BEEN CLUSTERED SEARCHING TO A DEPTH OF 1
INCONSISTENT EDGES HAVE BEEN DETERMINED BY A FACTOR OF 1.0000E 00
AND A SPREAD OF 5.0000E-01 STANDARD DEVIATIONS.

17 CLUSTERS DETECTED

CLUSTER 1 CONSISTS OF THE FOLLOWING 3 PATTERNS.

1	0	2.	9.	0.0
2	0	2.	12.	0.0
5	0	3.	14.	0.0

CLUSTER 2 CONSISTS OF THE FOLLOWING 2 PATTERNS.

15	0	7.	12.	0.0
17	0	8.	17.	0.0

CLUSTER 3 CONSISTS OF THE FOLLOWING 4 PATTERNS.

27	0	14.	21.	0.0
33	0	15.	20.	0.0
23	0	11.	24.	0.0
29	0	13.	15.	0.0

CLUSTER 4 CONSISTS OF THE FOLLOWING 2 PATTERNS.

26	0	14.	12.	0.0
28	0	15.	8.	0.0

CLUSTER 5 CONSISTS OF THE FOLLOWING 3 PATTERNS.

10	0	7.	27.	0.0
12	0	5.	25.	0.0
8	0	3.	24.	0.0

CLUSTER 6 CONSISTS OF THE FOLLOWING 5 PATTERNS.

73	0	23.	22.	0.0
119	0	27.	17.	0.0
46	0	21.	26.	0.0
118	0	27.	15.	0.0
22	0	19.	28.	0.0

CLUSTER 7 CONSISTS OF THE FOLLOWING 1 PATTERN.

123	0	27.	29.	0.0
-----	---	-----	-----	-----

CLUSTER 8 CONSISTS OF THE FOLLOWING 123 PATTERNS.

95	0	25.	36.	0.0
123	0	28.	30.	0.0
134	0	28.	40.	0.0
156	0	34.	40.	0.0
125	0	28.	41.	0.0
121	0	27.	40.	0.0
137	0	33.	40.	0.0
137	0	29.	41.	0.0
137	0	27.	41.	0.0
107	0	26.	40.	0.0
138	0	33.	41.	0.0
108	0	28.	41.	0.0
66	0	28.	40.	0.0
109	0	33.	42.	0.0
27	0	25.	41.	0.0
80	0	24.	40.	0.0
140	0	30.	41.	0.0
144	0	29.	42.	0.0
11	0	24.	41.	0.0
71	0	11.	31.	0.0
141	0	30.	44.	0.0

Figure 3.4: Best Clustering Found

MODELING OF SHADOWS IN RADAR CLUTTER

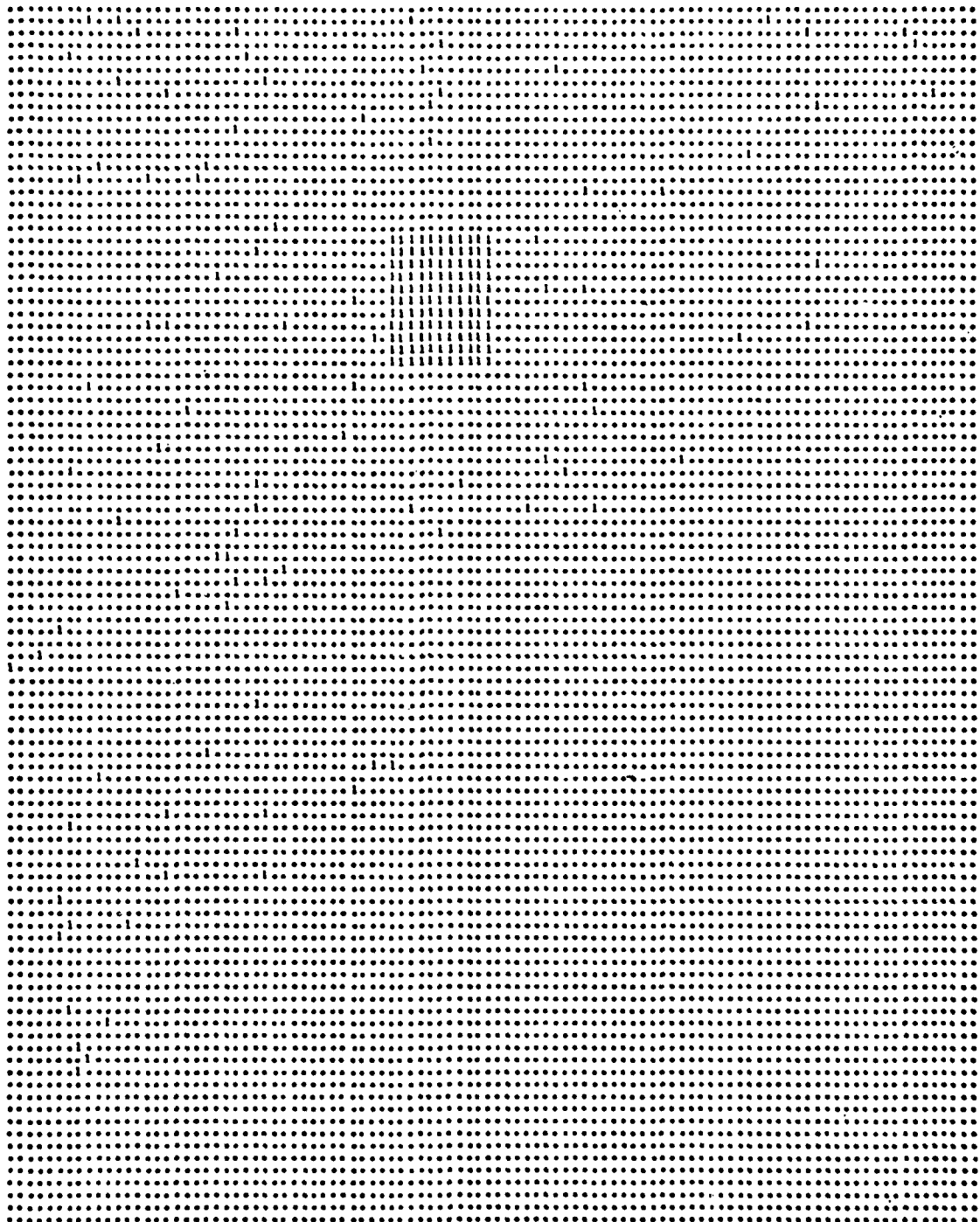


Figure 3.5: Data Set for Tree Example

MODELING OF SHADOWS IN RADAR CLUTTER

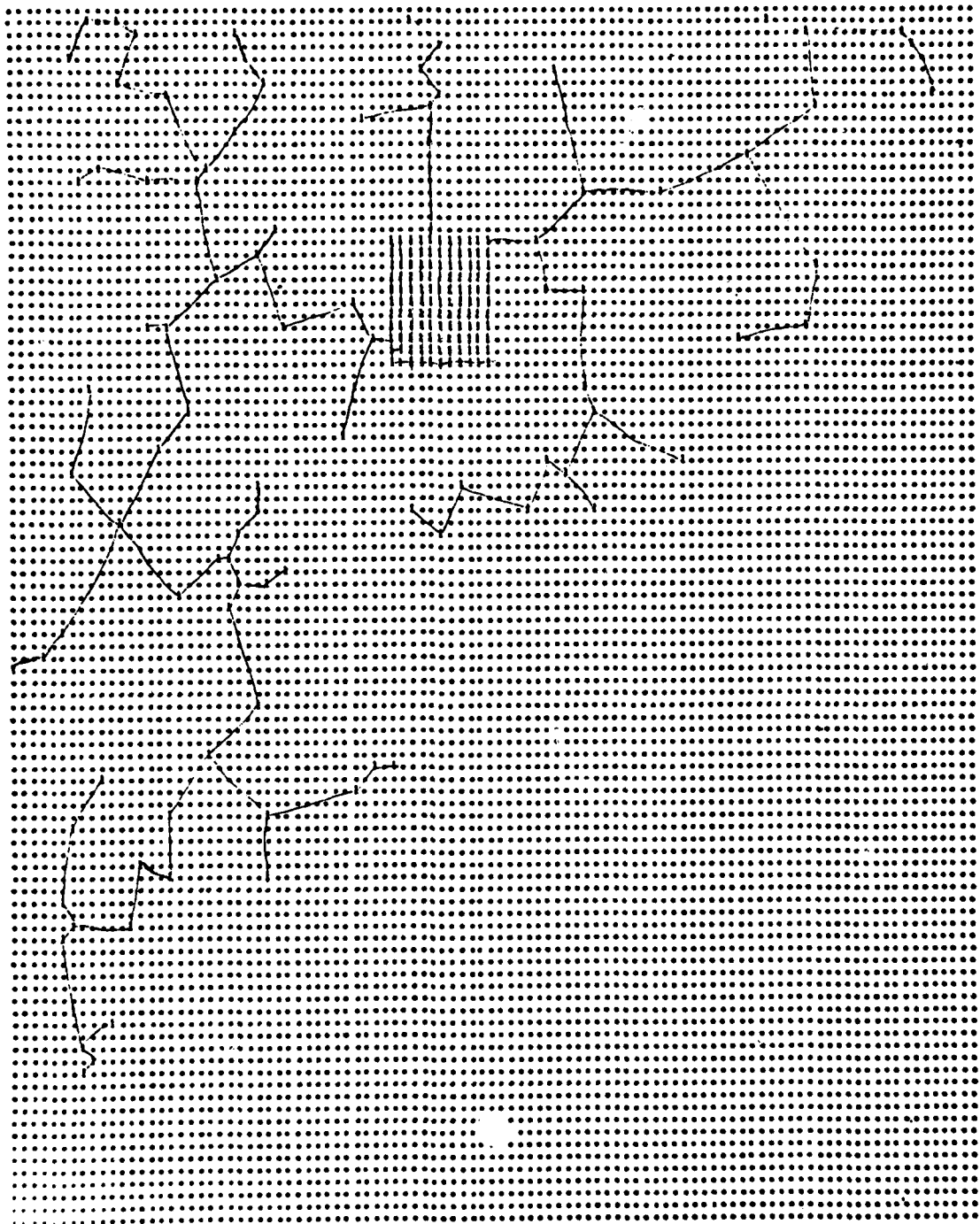


Figure 3.6: Minimal Spanning Tree

MODELING OF SHADOWS IN RADAR CLUTTER

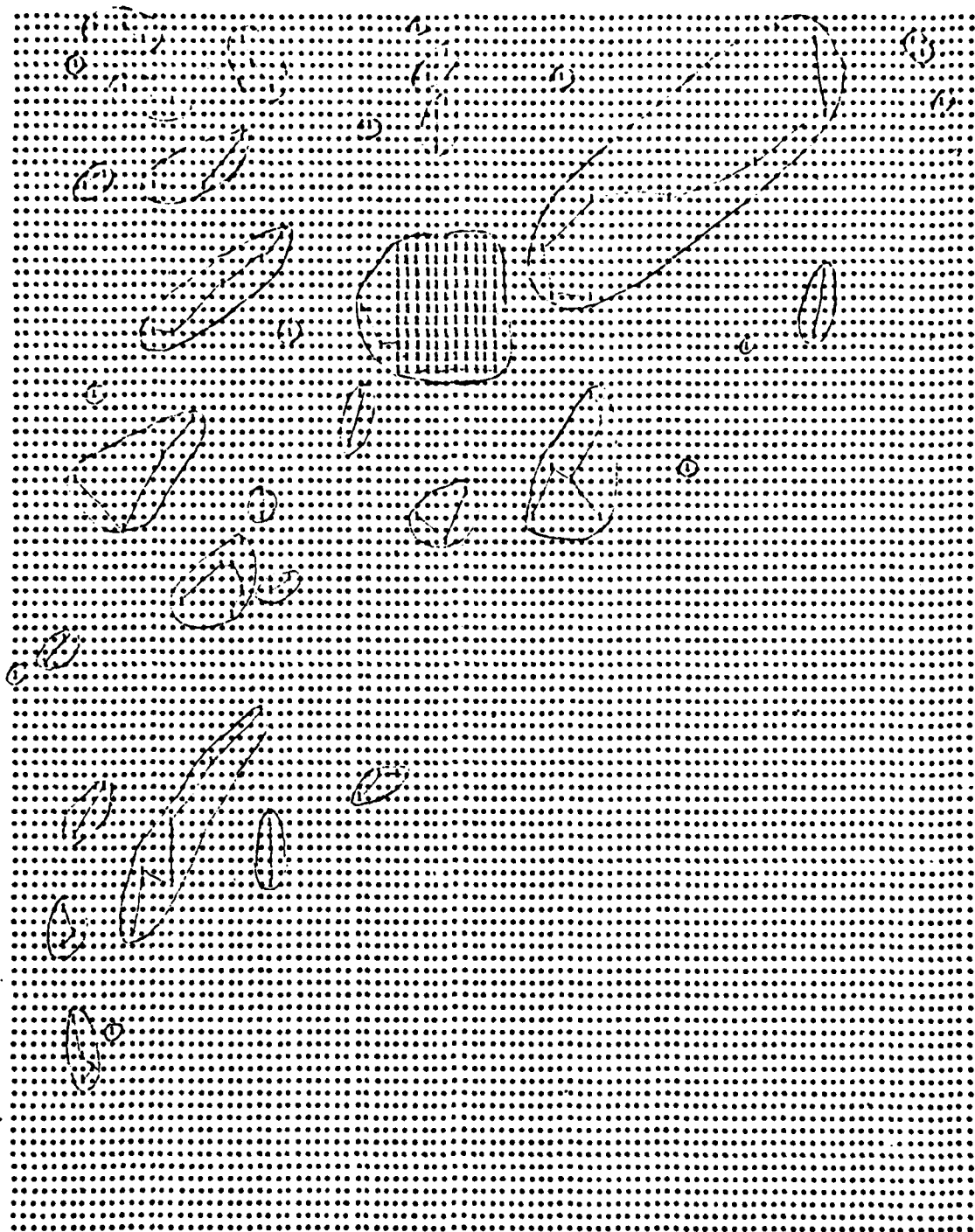


Figure 3.7: Best Clustering Found

MODELING OF SHADOWS IN RADAR CLUTTER



Figure 4.1: Point-to-Point Local Variance

MODELING OF SHADOWS IN RADAR CLUTTER

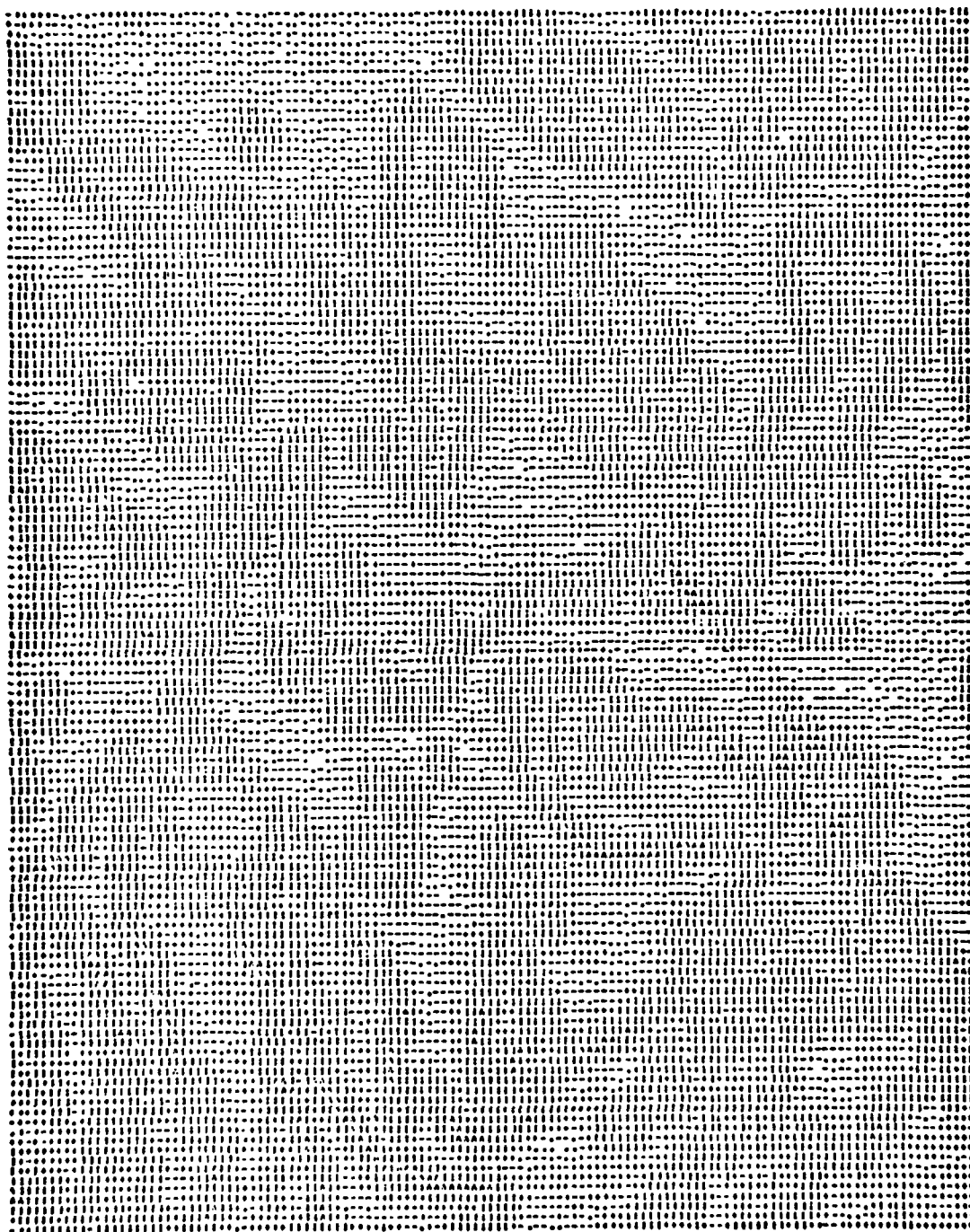


Figure 4.2: Point-to-Point Local Gradient

MODELING OF SHADOWS IN RADAR CLUTTER



Figure 4.3: Location of Radar in Upper Quadrant

MODELING OF SHADOWS IN RADAR CLUTTER

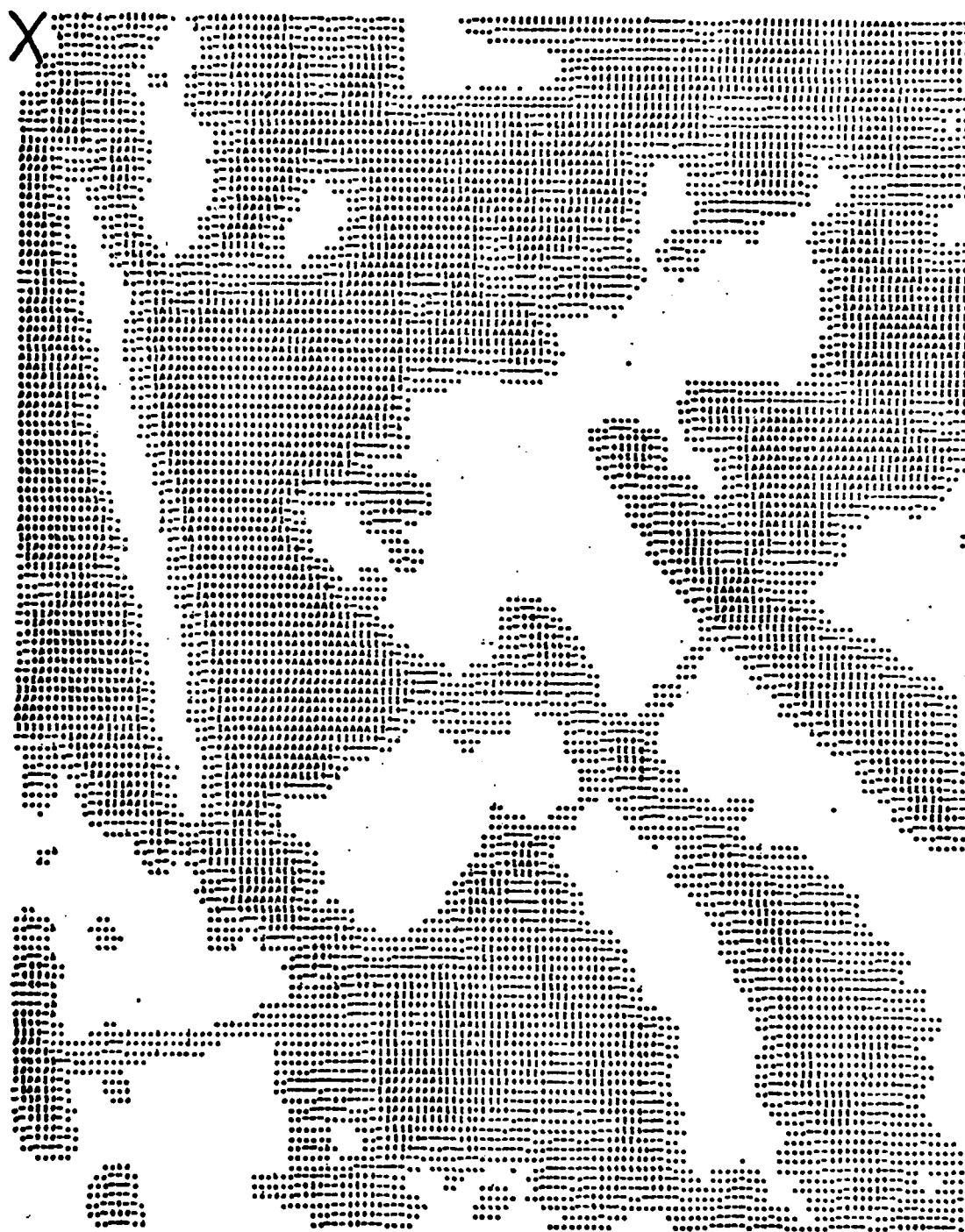


Figure 4.4: Location of Radar in Lower Quadrant

MODELING OF SHADOWS IN RADAR CLUTTER

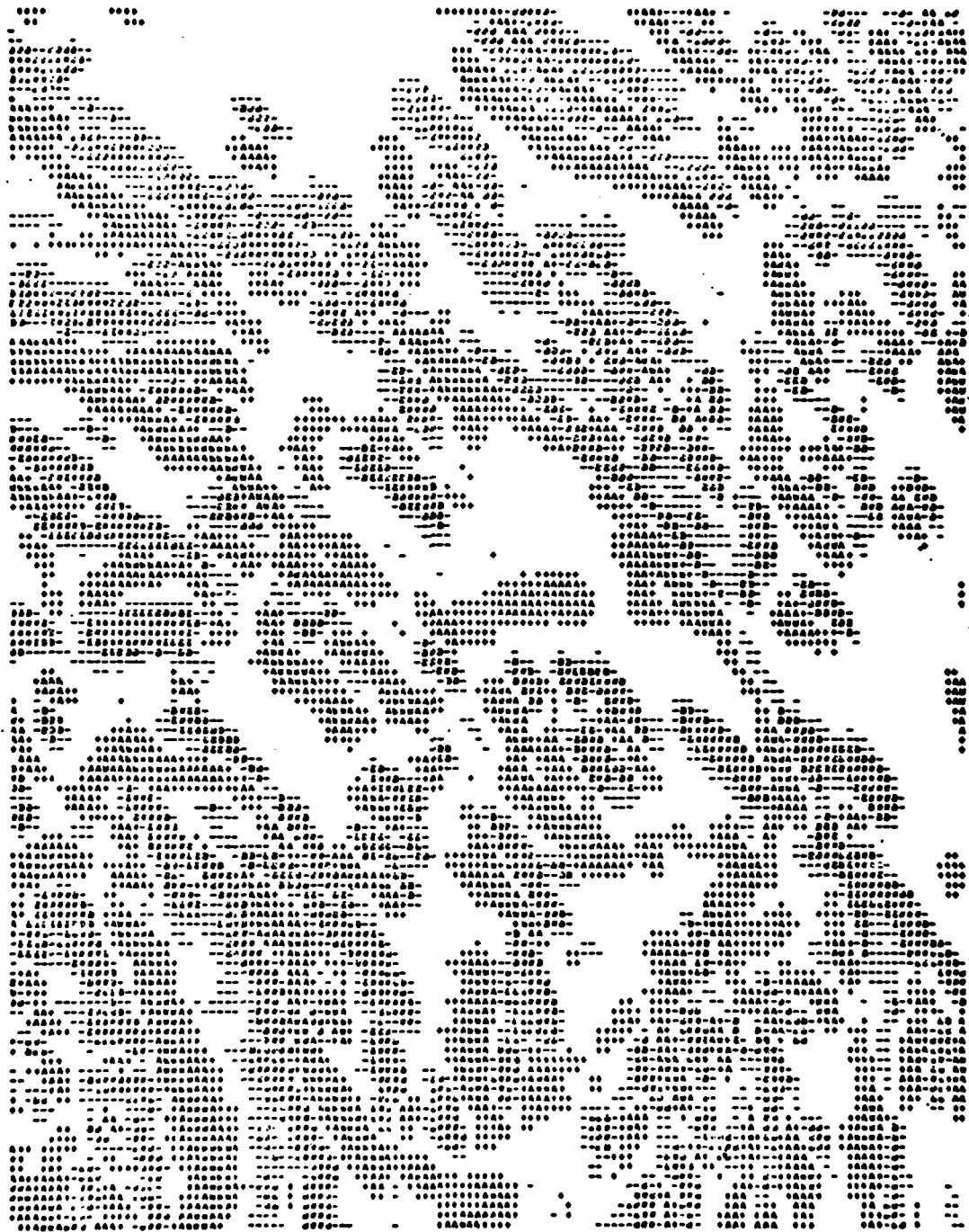


Figure 4.5: Radial Derivative, Upper Quadrant

MODELING OF SHADOWS IN RADAR CLUTTER



Figure 4.6: Radial Derivative, Lower Quadrant

MODELING OF SHADOWS IN RADAR CLUTTER



Figure 4.7: Radial Derivative and Shadows

MODELING OF SHADOWS IN RADAR CLUTTER



Figure 4.8: Precursors of Shadows

MODELING OF SHADOWS IN RADAR CLUTTER

```

C THIS SUBROUTINE READS PARAMETERS, COMPUTES STORAGE AND CALLS MAJOR
C PROGRAM SEGMENTS. IT IS FOR A NON-HIERARCHICAL CLUSTERING JOB USING
C ONE OF THE METHODS PROGRAMMED AS A VERSION OF SUBROUTINE "KMEAN".
C EVERY JOB REQUIRES THREE USER SUPPLIED DECK SEGMENTS.
C
C 1. PROGRAM "KMEAN" PERFORMS THE FOLLOWING TASKS.
C   A. ASSIGNS INPUT/OUTPUT UNITS.
C   B. DETERMINES THE DIMENSION OF THE "X" ARRAY AND SETS THIS
C      DIMENSION TO "LIMIT".
C   C. CALLS SUBROUTINE "EXEC2" (FORMERLY "EXEC")
C
C 2. SUBROUTINE "USER" IS EMPLOYED TO READ THE COMPLETE SET OF SCORES
C   ON THE VARIABLES FOR ONE DATA UNIT.
C
C 3. FUNCTION "DIST" COMPUTES THE DISTANCE BETWEEN TWO DATA UNITS OR
C   BETWEEN A DATA UNIT AND A CLUSTER CENTER. THE USER CAN SPECIFY
C   ANY DESIRED DISTANCE FUNCTION AND WEIGHT THE VARIABLES IN ANY
C   MANNER.
C
C NOTE THAT SCALING AND TRANSFORMATION OF VARIABLES CAN BE
C ACCOMPLISHED EITHER IN SUBROUTINE "USER" OR IN SUBROUTINE "DIST".
C
C *****
C NOTE: MODIFIED SUBROUTINE "EXEC" IS CALLED "EXEC2", AND CALLS
C "RESULT2". "KMEAN" HAS NOT BEEN ALTERED.
C *****
C
C-----
C INPUT SPECIFICATIONS
C CARD 1  TITLE
C CARD 2  PARAMETER CARD
C COLS 1-4  NE=NUMBER OF ENTITIES (DATA UNITS)
C COLS 5-13 NV=NUMBER OF VARIABLES
C COLS 14-18 NC=NUMBER OF CLUSTERS
C COLS 19-20 NTIN=INPUT UNIT FOR THE DATA SET
C           NTIN=5, CARD READER
C           NTIN=6,5, TAPE OR DISK FILE
C           NTOUT=OUTPUT UNIT FOR SAVING CLUSTER MEMBERSHIP LISTS
C           NTOUT=7, CARD PUNCH
C           NTOUT=6, DO NOT SAVE MEMBERSHIP LISTS
C COLS 21-22 MINREL=TERMINATION PARAMETER. CLUSTERING ENDS WHEN A
C           CYCLE THROUGH THE DATA SET RESULTS IN "MINREL"
C           OR FEWER CHANGES IN CLUSTER MEMBERSHIPS
C COLS 23-27 MINREL=0.5, ITERATE TO COMPLETE CONVERGENCE
C           IPART=INITIAL PARTITION PARAMETER
C COLS 28-29 IPART=1, SEE POINTS SELECTED FROM THE DATA UNITS.
C           READ THE SEQUENCE NUMBERS FOR THE CHOSEN DATA
C           UNITS FROM CARD(5) 3 IN 2014 FORMAT. IF THE
C           DATA SET IS NOT STORED IN CORE, THE LIST OF
C           SEQUENCE NUMBERS MUST BE IN ASCENDING ORDER
C           IPART=2, THE DATA UNITS ARE GROUPED INTO AN INITIAL
C           PARTITION IN THE INPUT SEQUENCE WITH THE
C           FIRST "NUMBER(1)" IN CLUSTER 1, THE NEXT
C           "NUMBER(2)" IN CLUSTER 2 ETC. READ THE
C           "NUMBER" ARRAY FROM CARD(5) 3 IN 2014 FORMAT.
C           IPART=3, THE SCORE VECTORS FOR THE SEED POINTS ARE
C           READ FROM CARD(5) 4 IN FORMAT "FMT" WHICH IS
C           READ FROM CARD 3.
C COLS 30-31 METHOD=PARAMETER FOR CHOOSING THE ALGORITHM IN ONE
C           VERSION OF SUBROUTINE "KMEAN"
C           METHOD=1, JANCEY ALGORITHM
C           METHOD=NE=1, FORGY ALGORITHM
C
C *** CARDS 3 AND 4 ARE READ IN SUBROUTINE "KMEAN" ACCORDING TO THE
C *** PROCEDURE SPECIFIED BY THE CHOSEN VALUE OF "IPART". NOTE THAT THE
C *** BASIC K-MEANS METHOD OF MACQUEEN SIMPLY USES THE FIRST "NC" DATA
C *** UNITS AS CLUSTER SEED POINTS AND THEREFORE IGNORES THE "IPART"
C *** PARAMETER.
C-----
C STORAGE ALLOCATIONS IN THE "X" ARRAY
C X(1) TO X(2)-1  NC*NV WORDS--STORAGE OF THE CENTR ARRAY
C X(2) TO X(3)-1  NC WORDS--STORAGE OF THE NUMBER ARRAY
C X(3) TO X(4)-1  NV WORDS--STORAGE OF THE MEMBER ARRAY
C X(4) TO X(5)-1  NC*NV WORDS--STORAGE OF THE TOTAL ARRAY
C X(5) TO X(6)-1  NV OR NV*NV WORDS--STORAGE OF THE DATA ARRAY
C X(6) TO X(7)-1  NE WORDS--STORAGE OF THE LIST ARRAY IN "RESULT"
C
C THE STORAGE OF THE "LIST" ARRAY AFTER THE "DATA" ARRAY NOW IMPLIES THAT
C "MAX" MUST BE THE VALUE OF "NV".

```

Figure A.1: Forgy-Jancey Comments

MODELING OF SHADOWS IN RADAR CLUTTER

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C-----
C INPUT SPECIFICATIONS
C CARD 1  TITLE
C CARD 2  PARAMETER CARD
C COLS 1-3  NC=NUMBER OF CLUSTERS (DATA UNITS)
C COLS 7-13  N=NUMBER OF VARIABLES
C COLS 14-19  NCM=NUMBER OF CLUSTERS
C COLS 19-23  NIN=INPUT UNIT FOR THE DATA SET
C COLS 21-22  NOUT=OUTPUT UNIT FOR SAVING CLUSTER MEMBERSHIP LISTS
C COLS 23-27  NINCL=ITERATION PARAMETER. CLUSTERING ENDS WHEN A
C              CYCLE THROUGH THE DATA SET RESULTS IN "MINREL"
C              OR FASTER CHANGES IN CLUSTER MEMBERSHIPS
C COLS 28-29  NINCL=ITERATION PARAMETER TO COMPLETE CONVERGENCE
C              IPART=INITIAL PARTITION PARAMETER
C              IPART=1, SEED POINTS ARE SELECTED FROM THE DATA UNITS.
C              READ THE SEQUENCE NUMBERS FOR THE CHOSEN DATA
C              UNITS FROM CARD(S) 7 IN 2014 FORMAT. IF THE
C              DATA SET IS NOT STORED IN CORE, THE LIST OF
C              SEQUENCE NUMBERS MUST BE IN ASCENDING ORDER
C              IPART=2, THE DATA UNITS ARE GROUPED INTO AN INITIAL
C              PARTITION IN THE INPUT SEQUENCE WITH THE
C              FIRST "NUMBER(1)" IN CLUSTER 1, THE NEXT
C              "NUMBER(2)" IN CLUSTER 2 ETC. READ THE
C              "NUMBER" ARRAY FROM CARD(S) 3 IN 2014 FORMAT.
C              IPART=3, THE SEED VECTORS FOR THE SEED POINTS ARE
C              READ FROM CARD(S) 4 IN FORMAT "FMT" WHICH IS
C              READ FROM CARD 3.
C COLS 30-31  METHOD=PARAMETER FOR CHOOSING THE ALGORITHM IN ONE
C              VERSION OF SUBROUTINE "KMEAN"
C              METHOD=1, JANCEY ALGORITHM
C              METHOD=NE.1, FORSY ALGORITHM
C COLS 32-39  NCMAX=MAX NUMBER OF CLUSTERS FOR OUTLIER ROUTINE
C              NCMAX=NC, DON'T DO OUTLIER ROUTINE
C              NCMAX=LE.0, USE NC AS NCMAX (I.E. NO LIMIT ON CLUSTERS)
C COLS 40-43  OUTLYR=COEFFICIENT (BETWEEN 0 AND 1 INCLUSIVE) FOR THE
C              OUTLIER ROUTINE (NUMBER IN F4.2 FORMAT)
C              OUTLYR=1., MAX AMOUNT OF OUTLYING CLUSTERS
C              OUTLYR=0., NO OUTLYING CLUSTERS ALLOWED.
C
C*** CARDS 3 AND 4 ARE READ IN SUBROUTINE "KMEAN" ACCORDING TO THE
C*** PROCEDURE SPECIFIED BY THE CHOSEN VALUE OF "IPART". NOTE THAT THE
C*** BASIC K-MEANS METHOD OF MACQUEEN SIMPLY USES THE FIRST "NC" DATA
C*** UNITS AS CLUSTER SEED POINTS AND THEREFORE IGNORES THE "IPART"
C*** PARAMETER.
C-----
C STORAGE ALLOCATIONS IN THE "X" ARRAY
C X(1) TO X(N2-1)  NC*NV WORDS--STORAGE OF THE CENTR ARRAY
C X(N2) TO X(N3-1)  NC WORDS--STORAGE OF THE NUMB ARRAY
C X(N3) TO X(N4-1)  NE WORDS--STORAGE OF THE MEMBR ARRAY
C X(N4) TO X(N5-1)  NC*NV WORDS--STORAGE OF THE TOTAL ARRAY
C X(N5) TO X(N6-1)  NV OR NC*NV WORDS--STORAGE OF THE DATA ARRAY
C X(N6) TO X(N7)   NE WORDS--STORAGE OF THE LIST ARRAY IN "RESULT"
C
C THE STORAGE OF THE "LIST" ARRAY AFTER THE "DATA" ARRAY NOW IMPLIES THAT
C
C "MAX" MUST BE THE VALUE OF "N7".
C
C*****
C NOTE:
C SINCE NC CAN BE INCREASED BY THE OUTLIER ROUTINE, THE
C ALLOCATIONS IN THE ARRAYS ARE BASED ON NCMAX, NOT NC.
C THIS CAN INCREASE STORAGE REQUIREMENTS FASTER THAN EXPECTED.
C*****

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Figure A.2: Outlier Comments

MODELING OF SHADOWS IN RADAR CLUTTER

```

FORTRAN IV G LEVEL 21          EXEC          DATE = 79365          09/26/50

0001          SUBROUTINE EXEC(X,LIMIT)
C
C THIS SUBROUTINE READS PARAMETERS, COMPUTES STORAGE AND CALL'S MAJOR
C PROGRAM SEGMENTS NEEDED FOR A NON-HIERARCHIAL CLUSTERING JOB USING
C ONE OF THE METHODS PROGRAMMED AS A VERSION OF SUBROUTINE "KMEAN"
C
C NOW COMMENTS AND A FULL EXPLANATION CAN BE FOUND IN FILE "00.FCOMMENT",
C OR BY OBTAINING THE REPORT THAT WAS A SOURCE OF THIS PROGRAM.
C
0002          DIMENSION X(1),TITLE(20)
0003          READ (5,1000) TITLE
0004          READ (5,1100) NE,NV,NC,NTIN,NTOUT,MINREL,IPART,METHOD
0005          WRITE (6,2000) TITLE
0006          WRITE (6,2100) NE,NV,NC,NTIN,NTOUT,MINREL,IPART,METHOD
0007          N1=1
0008          N2=N1+NC+NV
0009          N3=N2+NC
0010          N4=N3+NE
0011          N5=N4+NC+NV
C "N6" MAY (AND WILL) BE INCREASED IN "KMEAN"
0012          N6=N5+NV-1
0013          N7=N4+NE-1
0014          MAX=N6
0015          WRITE (6,2200) MAX,LIMIT
0016          IF (MAX.GT. LIMIT) STOP
0017          CALL KMEAN(X(N1),X(N2),X(N3),X(N4),X(N5),N5,NE,NV,NC,NTIN,MINREL,
* IPART,METHOD,LIMIT)
0018          CALL RESULT(X(N1),X(N2),X(N3),X(N4),TITLE,NE,NV,NC,NTOUT,
* X(N4),X(N5))
0019          RETURN
0020          FORMAT(20A4)
0021          FORMAT(15I)
0022          FORMAT(1-11,20A4)
0023          FORMAT('ONE =',15,/, ' NV =',18,/, ' NC =',18,/, ' NTIN =',16,/,
* ' NTOUT =',15,/, ' MINREL =',14,/, ' IPART =',15,/, ' METHOD =',14)
0024          FORMAT('REQUIRED STORAGE =',18, ' WORDS',/,
* 'ALLOTTED STORAGE =',18, ' WORDS')
0025          END

```

Figure A.3: Subroutine EXEC

MODELING OF SHADOWS IN RADAR CLUTTER

```

FORTRAN IV G LEVEL 21          MAIN          DATE = 79365          10/02/66

0001      C ALTERED SUBROUTINE EXEC--CALLS KMEAN, RESULT2
          C SUBROUTINE EXEC2(X,LIMIT)
          C
          C THIS SUBROUTINE READS PARAMETERS, COMPUTES STORAGE AND CALLS MAJOR
          C PROGRAM SEGMENTS NEEDED FOR A MIN-HIERARCHICAL CLUSTERING JOB USING
          C ONE OF THE METHODS PROGRAMMED AS A VERSION OF SUBROUTINE "KMEAN"
          C
          C MORE COMMENTS AND A FULL EXPLANATION CAN BE FOUND IN FILE "JO.FCOMMENT",
          C OR BY OBTAINING THE REPORT THAT WAS A SOURCE OF THIS PROGRAM.
          C ---CHANGES MADE TO "N6", "N7", SUBROUTINE "RESULT" IS "RESULT2",
          C ---CHANGED INPUT FORMATS (DOCUMENTED IN ROSCOE FILE "FCOMMENT")
          C
0002      DIMENSION X(1),TITLE(20)
0003      READ (5,1000) TITLE
0004      READ (5,1100) NE,NV,NC,NTIN,NTOUT,MINREL,IPART,METHOD
0005      WRITE (6,2000) TITLE
0006      WRITE (6,2100) NE,NV,NC,NTIN,NTOUT,MINREL,IPART,METHOD
0007      N1=1
0008      N2=N1+NC+NV
0009      N3=N2+NC
0010      N4=N3+NE
0011      N5=N4+NC+NV
          C "N6" IS NOT THE SAME AS IN ORIGINAL PROGRAM, ALSO "N7" CHANGED, TOO
0012      N6=N5+NV+NE
0013      N7=N6+NE-1
0014      MAX=N7
0015      WRITE (6,2200) MAX,LIMIT
0016      IF (MAX.GT. LIMIT) STOP
0017      CALL KMEAN(X(N1),X(N2),X(N3),X(N4),X(N5),N5,NE,NV,NC,NTIN,MINREL,
          C IPART,METHOD,INIT)
0018      CALL RESULT2(X(N1),X(N2),X(N3),X(N4),X(N5),TITLE,NE,NV,NC,NTOUT,
          C X(N4),X(N5))
0019      RETURN
0020      1000  FORMAT(21A4)
0021      1100  FORMAT(15,215,212,15,212)
0022      2000  FORMAT(111,23A4)
0023      2100  FORMAT('ONE =',15,/, 'NV =',15,/, 'NC =',15,/, 'NTIN =',15,/,
          C 'IPART =',15,/, 'MINREL =',15,/, 'IPART =',15,/, 'METHOD =',14)
0024      2200  FORMAT('REQUIRED STORAGE =',18, ' WORDS',/,
          C 'ALLOTTED STORAGE =',18, ' WORDS')
0025      END

```

Figure A.4: Subroutine EXEC2

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MODELING OF SHADOWS IN RADAR CLUTTER.(U)
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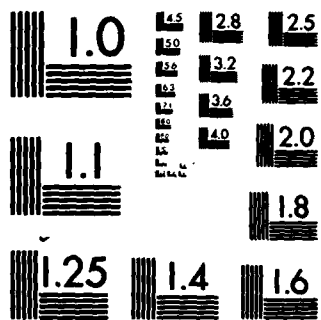
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END

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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

MODELING OF SHADOWS IN RADAR CLUTTER

```

FORTRAN IV & LVLVL 21      MAIN      DATE = 79365      10/21/79

0001      C ALTERN SUBROUTINE EXEC--CALLS KMEAN?, RESULT2
          SUBROUTINE EXEC(CN,LIMIT)
          C
          C THIS SUBROUTINE READS PARAMETERS, COMPUTES STORAGE AND CALLS MAJOR
          C PROGRAM SECTIONS NEEDED FOR A MIN-MILBURNAL CLUSTERING JOB USING
          C ONE OF THE METHODS PROGRAMMED AS A VERSION OF SUBROUTINE "KMEAN2"
          C
          C NOW COMMENTS AND A FULL EXPLANATION CAN BE FOUND IN FILE "DD.FCCOMMENT"
          C OR BY EXAMINING THE REPORT THAT WAS A SOURCE OF THIS PROGRAM.
          C ---CHANGES MADE TO KMEAN, N77, SUBROUTINE "RESULT2" IS "RESULT3".
          C ---CHANGED INPUT FORMAT (DOCUMENTED) IN BDCODE FILE "FCCOMMENT"
          C -----
          C INPUT SPECIFICATIONS
          C CARD 1 TITLE
          C CARD 2 PARAMETER CARD
          C COLS 1- 4 NF=NUMBER OF ENTITIES (DATA UNITS)
          C COLS 9-11 NV=NUMBER OF VARIABLES
          C COLS 14-16 NC=NUMBER OF CLUSTERS
          C COLS 19-23 NTIN=INPUT UNIT FOR THE DATA SET
          C NTIN=5, CARD HEADER
          C NTIN=6,5, TAPE OR DISK FILE
          C COLS 21-22 NTOUT=OUTPUT UNIT FOR SAVING CLUSTER MEMBERSHIP LISTS
          C NTOUT=7, CARD PUNCH
          C NTOUT=6,0, DO NOT SAVE MEMBERSHIP LISTS
          C COLS 23-27 MINREL=RELATIONSHIP PARAMETER. CLUSTERING ENDS WHEN A
          C CYCLE THROUGH THE DATA SET RESULTS IN "MINREL"
          C OR FEWER CHANGES IN CLUSTER MEMBERSHIPS
          C MINREL=0,0, ITERATE TO COMPLETE CONVERGENCE
          C COLS 28-29 IPART=INITIAL PARTITION PARAMETER
          C IPART=1, SEED POINTS ARE SELECTED FROM THE DATA UNITS.
          C READ THE SEQUENCE NUMBERS FOR THE CHOSEN DATA
          C UNITS FROM CARD(1:3) 3 IN 2014 FORMAT. IF THE
          C *****001) IEY032) COMMENTS DELETED *****
          0002 DIMENSION X(1),TITLE(20)
          0003 READ (5,1000) TITLE
          0004 READ (5,1100) NF,NV,NC,NTIN,NTOUT,MINREL,IPART,METHOD,NCHMAX,
          C * OUTLYR
          0005 WRITE (6,2001) TITLE
          0006 WRITE (6,2100) NF,NV,NC,NTIN,NTOUT,MINREL,IPART,METHOD,NCHMAX,
          C * OUTLYR
          0007 IF (NCHMAX .LE. 0) NCHMAX=NF
          0008 N1=1
          0009 N2=N1+NCHMAX*NV
          0010 N3=N2+NCHMAX
          0011 N4=N3+NE
          0012 N5=N4+NCHMAX*NV
          C "N6" IS NOT THE SAME AS IN ORIGINAL PROGRAM. ALSO "N7" CHANGED. TOO
          0013 N6=N5+NV*NE
          0014 NTING=N6-1
          0015 NAX=N7
          0016 WRITE (6,2200) MAX,LIMIT
          0017 IF (MAX .GT. LIMIT) CALL SVC(15)
          0018 CALL KMEAN2(X(1),X(2),X(3),X(4),X(5),N5,NF,NV,NC,NTIN,MINREL,

```

```

FORTRAN IV G LEVEL 21                                EXEC3                                DATE = 79365                                10/21/79

0019      * (PART,NTIME,LIMIT,NCMAX,OUTLYR)
          * CALL RSULT2(X(N1),X(N2),X(N3),X(N6),TITLE,NE,NV,NC,NTOUT,
          * X(N4),X(N5))
0020      * RETURN
0021      1000  FORMAT(73A4)
0022      1100  FORMAT(13,215,212,15,212,18,F4.2)
0023      2000  FORMAT(1M,23A4)
0024      2100  FORMAT(10M,15,/, ' NV =',18,/, ' NC =',18,/, ' NTIN =',18,/,
          * ' NTOUT =',15,/, ' NINM =',18,/, ' PART =',15,/, ' METHOD =',14,
          * ' /', ' NCMAX =',15,/, ' OUTLYR =',F4.2)
0025      2700  FORMAT('9RFOUT1PD STORAGE =',18, ' WORDS',/,
          * '9ALLOTTE7 STORAGE =',18, ' WORDS')
0026      * END

```

Figure A.5: Subroutine EXEC3

MODELING OF SHADOWS IN RADAR CLUTTER

```

FORTRAN IV 5 LEVEL 21      KNEAN      DATE = 79365      07/51/30
0001      SUBROUTINE KNEAN(CENTR,NUMBR,MEMBR,TOTAL,DATA,N5,NE,NV,NC,NFIN,
      * MINML,IPART,NFINML,LIMIT)
      C-----
      C VERSION 1., THE DATA SET IS STORED IN CENTRAL MEMORY.
      C-----
      C THIS SUBROUTINE ITERATIVELY SORTS "NE" DATA UNITS INTO "NC" CLUSTERS
      C USING THE ALGORITHM OF (METHOD .NE. 1)
      C-----
      C FURDY, F.W., CLUSTER ANALYSIS OF MULTIVARIATE DATA, EFFICIENCY
      C VERSUS INTERPRETABILITY OF CLASSIFICATIONS, PAPER PRESENTED AT THE
      C DIOMETRIC SOCIETY (UNAM) MEETINGS, RIVERSIDE, CALIFORNIA, JUNE
      C 1969. ABSTRACT IN RIOMETRICS, VOLUME 21, NUMBER 3, P 768.
      C-----
      C OR THE ALGORITHM OF (METHOD = 1)
      C-----
      C JANCEY, R.C., MULTIDIMENSIONAL GROUP ANALYSIS, AUSTRALIAN JOURNAL
      C OF STATISTICS, VOLUME 14, NUMBER 1, APRIL 1968, PP 127-130.
      C-----
      C CENTR(NV+J-1)+1)=SCORE ON THE I-TH VARIABLE FOR J-TH CLUSTER CENTROID
      C TOTAL(NV+J-1)+1)=TOTAL SCORE ON I-TH VARIABLE FOR DATA UNITS THUS
      C FAR ALLOCATED TO THE J-TH CLUSTER
      C NUMBR(J)=NUMBER OF DATA UNITS THUS FAR ALLOCATED TO THE J-TH CLUSTER
      C MEMBR(K)=CLUSTER TO WHICH THE K-TH DATA UNIT CURRENTLY BELONGS
      C DATA(NV+(K-1)+1)=SCORE ON I-TH VARIABLE FOR K-TH DATA UNIT
      C-----
0002      DIMENSION CENTR(1),TOTAL(1),NUMBR(1),MEMBR(1),DATA(1),FMT(20),
      * NAME(4)
0003      DATA NAME/' F','ORGY',' JA','NCEY'/
0004      I=1
0005      IF (METHOD .EQ. 1) I=3
0006      WRITE(6,2000) NAME(1),NAME(1+1)
      C CHECK FOR SUFFICIENT STORAGE
0007      N5=N5+NV+NV-1
0008      WRITE(6,2100) N5,LIMIT
0009      IF (N5 .GT. LIMIT) STOP
      C ESTABLISH INITIAL PARTITION
0010      IF (IPART .NE. 3) GO TO 20
      C SEED POINTS ARE READ DIRECTLY FROM CARDS
0011      READ (5,1000) FMT
0012      WRITE(6,2200) FMT
0013      WRITE(6,2300)
0014      J=0
0015      DO 10 J=1,NC
0016      READ(5,FMT) (CENTR(J+1),I=1,NV)
0017      WRITE(6,2400) (CENTR(J+1),I=1,NV)
0018      J1=J+NV
0019      GO TO 30
0020      C IPART=1 OR 2
0021      WRITE(6,2500) IPART
0022      READ(5,1100) (NUMBR(J),J=1,NC)
      WRITE(6,2600) (NUMBR(J),J=1,NC)

```

Figure A.6 (Part 1): Subroutine KNEAN

MODELING OF SHADOWS IN RADAR CLUTTER

```

PORTMAN IV 6 LEVEL 21                                KMEAN                                DATE = 79366                                09/51/30

0023      C READ THE DATA SET INTO CENTRAL MEMORY
0024      30      KI=1
0025      DO 40 K=1,NE
0026      CALL USER (DATA(K))
0027      KI=KI+NV
0028      C IF (IPART.EQ. 3) GO TO 100
0029      C IF (IPART IS 1 OR 2 SET UP THE SEED POINTS
0030      IF (IPART.EQ. 2) GO TO 60
0031      C IPART=1: THE DATA UNIT WITH SEQUENCE NUMBER "NUMBER(J)" IS USED AS
0032      C THE J-TM SEED POINT
0033      ON 50 J=1,NC
0034      NJ=(NUMBER(J)-1)*NV
0035      J1=(J-1)*NV
0036      DO 50 I=1,NV
0037      CFNTR(J1+1)=DATA(NJ+I)
0038      CONTINUE
0039      50      GO TO 100
0040      C IPART=2: THE DATA UNITS ARE GROUPED INTO CLUSTERS WITH THE J-TM
0041      C CLUSTER HAVING "NMBR(J)" MEMBERS.
0042      60      K=0
0043      J1=NV
0044      C ACCUMULATE THE TOTAL SCORE ON EACH VARIABLE FOR EACH CLUSTER
0045      DO 80 J=1,NC
0046      N1=NUMBER(J)
0047      J1=J1+NV
0048      DO 70 I=1,NV
0049      TOTAL(J1+I)=0.
0050      ON 80 KJ=1,NJ
0051      K=K+1
0052      NFNTR(K)=J
0053      K1=(K-1)*NV
0054      DO 80 I=1,NV
0055      J2=J1+I
0056      TOTAL(J2)=TOTAL(J2)+DATA(K1+I)
0057      CONTINUE
0058      80      C COMPUTE THE CENTROIDS
0059      J1=0
0060      DO 90 J=1,NC
0061      ON 90 I=1,NV
0062      J1=J1+I
0063      CFNTR(J1)=TOTAL(J1)/NUMBER(J)
0064      CONTINUE
0065      90      GO TO 115
0066      C INITIALIZE ARRAYS
0067      100      ON 110 K=1,NC
0068      110      NFNTR(K)=0
0069      115      NFNTR=1
0070      C BEGINNING OF MAIN LOOP
0071      120      J1=0
0072      ON 130 J=1,NC
0073      NUMBER(J)=0
0074      ON 130 I=1,NV
0075      J1=J1+I

```

Figure A.6 (Part 2): Subroutine KMEAN

MODELING OF SHADOWS IN RADAR CLUTTER

```

PORTMAN IV & LEVFL 21                                KNEAH                                DATE = 79105                                00/51/30

0046      130      TOTAL(J1)=0.
0047      MINV=1.0
0048      TDIST=0
0049      C  ALLOCATE EACH DATA UNIT TO THE NEAREST CLUSTER CENTROID
0050      K=0
0051      DO 140 J=1,NF
0052      K2=K1+1
0053      J2=1
0054      C  COMPUTE DISTANCE TO FIRST CLUSTER CENTROID
0055      DNEF=DI*Y(DATA(K2),CFNTH(J2))
0056      JREF=1
0057      C  TEST DISTANCES TO REMAINING CLUSTER CENTROIDS
0058      DO 140 J2=2,NC
0059      J2=J2+1
0060      DTEST=DIST(DATA(K2),CFNTH(J2))
0061      IF (DTEST .GT. DNEF) GO TO 140
0062      DNEF=DTEST
0063      JREF=J
0064      C  CONTINUE
0065      C  ALLOCATE DATA UNIT "K" TO CLUSTER "JREF"
0066      NUMB(JREF)=NUMB(JREF)+1
0067      TDIST=TDIST+DNEF
0068      IF (JREF .EQ. 4*NRNCR()) GO TO 150
0069      C  THE DATA UNIT CHANGES ITS MEMBERSHIP
0070      MOVES=MOVES+1
0071      NFNRNCR()=JREF
0072      J1=JREF-1+1
0073      DO 150 I=1,NV
0074      J1=J1+1
0075      K1=K1+1
0076      TOTAL(J1)=TOTAL(J1)+DATA(K1)
0077      C  CONTINUE
0078      C  ALL DATA UNITS ALLOCATED. TEST FOR CONVERGENCE
0079      WRITE(6,770) MOVES,NPASS,TDIST
0080      NPASS=NPASS+1
0081      JREF=0
0082      IF (MOVES .GT. MINREL) GO TO 165
0083      IF (METHODD .NE. 1 .AND. MOVES .EQ. 0) RETURN
0084      JREF=1
0085      C  COMPUTE TRUE CLUSTER CENTROIDS—FORCING UPDATE
0086      170      J1=0
0087      DO 180 J=1,NC
0088      DO 180 I=1,NV
0089      J1=J1+1
0090      C  180  CENTR(J1)=TOTAL(J1)/NUMB(J)
0091      IF (JREF .EQ. 1) RETURN
0092      GO TO 120
0093      C
0094      185  IF (METHODD .NE. 1) GO TO 170
0095      C  JANCY UPDATE
0096      190      J1=0
0097      DO 200 J=1,NC
0098      DO 200 I=1,NV

```

```

PORTMAN IV G LEVEL 21                                KMEAN                                DATE = 79365                                09/31/36

0110 J1=J1+1
0111 CENTR(J1)=2.*TOTAL(J1)/NUMBR(J)-CENTR(J1)
0112 GO TO 123
0113 FORMAT(23A4)
0114 FORMAT(20I4)
0115 2000 FORMAT(1M0.2A4,
      * ' METHOD OF CLUSTER ANALYSIS. DATA SET STORED IN CORE')
0116 2100 FORMAT(10REQURD STORAGE ='.15,' WORDS',/,
      * ' 1ALLITTE' STORAGE ='.15,' WORDS')
0117 2200 FORMAT(10FORMAT'.20A4)
0118 2300 FORMAT('INITIAL CLUSTER CENTERS READ IN AS FOLLOWS',///)
0119 2400 FORMAT(1X,10F12.3)
0120 2500 FORMAT(1X,1PARY ='.12.', NUMBR ARRAY READ AS FOLLOWS',///)
0121 2620 FORMAT(1X,10I7)
0122 2700 FORMAT(140.1%, DATA UNITS MOVED ON ITERATION NUMBER=.13,/,
      * ' SUMME' DEVIATIONS ABOUT SEED POINTS =.E16.2)
0123 END

```

Figure A.6 (Part 3): Subroutine KMEAN

MODELING OF SHADOWS IN RADAR CLUTTER

```

PIMTRAN IV G LVPL 21      KMFAN2      DATE = 70365      00/50/01

0001      SUBROUTINE KMEAN2(IPART, NMEM, NMEMD, TOTAL, DATA, N1, N2, NV, NC, NTH,
      * NTHL, IPART, NTHM, L1, L2, NCAR, OUTL, VR)
      C
      C CENTRE(NV(J-1)) = SCORE ON THE I-TH VARIABLE FOR J-TH CLUSTER CENTRE
      C TOTAL(NV(J-1)) = TOTAL SCORE ON I-TH VARIABLE FOR DATA UNITS THIS
      C NTHM(J) = NUMBER OF DATA UNITS THIS FAR ALLOCATED TO THE J-TH CLUSTER
      C NTHL(J) = CLUSTER TO WHICH THE K-TH DATA UNIT CURRENTLY BELONGS
      C DATA(NV(K-1)) = SCORE ON I-TH VARIABLE FOR K-TH DATA UNIT
      C
      C DIMENSION CENTR(1), TOTAL(1), NUMBR(1), MEMBR(1), DATA(1), PNT(20),
      * NAME(4)
      C DATA NAME: 1 = 'PROV', 2 = 'JAC', 3 = 'NCEV'
      C
      C IF (NTHM .EQ. 1) I=3
      C WRITE(6,2000) NAME(1), NAME(2)
      C ESTABLISH INITIAL PARTITION
      C IF (IPART .NE. 3) GO TO 50
      C SEED POINTS ARE READ DIRECTLY FROM CARDS
      C READ(5,1000) PNT
      C WRITE(6,2000) PNT
      C WRITE(6,2000) PNT
      C J=1
      C DO 10 J=1, NC
      C READ(5, PNT) (CENTR(J+1), I=1, NV)
      C WRITE(5, P400) (CENTR(J+1), I=1, NV)
      C J=J+1
      C GO TO 30
      C IPART=1 OR 2
      C 20 WRITE(6,2000) (PART
      C READ(5,1000) (NUMBR(J), J=1, NC)
      C WRITE(6,2000) (NUMBR(J), J=1, NC)
      C READ THE DATA SET INTO CENTRAL MEMORY
      C 30 K=1
      C DO 40 K=1, NE
      C CALL USER (DATA(K))
      C K=K+1
      C IF (IPART .EQ. 3) GO TO 100
      C IF (IPART IS 1 OR 2 SET UP THE SEED POINTS
      C IF (IPART .EQ. 2) GO TO 60
      C IPART=1. THE DATA UNIT WITH SEQUENCE NUMBER "NUMBR(J)" IS USED AS
      C THE J-TH SEED POINT
      C DO 50 J=1, NC
      C NJ=(NUMBR(J)-1) NV
      C J=(J-1) NV
      C DO 50 I=1, NV
      C CENTR(J+1)=DATA(NJ+I)
      C 50 CONTINUE
      C GOTO 100
      C IPART=2. THE DATA UNITS ARE GROUPED INTO CLUSTERS WITH THE J-TH
      C CLUSTER HAVING "NUMBR(J)" MEMBERS.
      C 60 K=0
      C J=NV
  
```

Figure A.7 (Part 1): Subroutine KMEAN2

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MODELING OF SHADOWS IN RADAR CLUTTER

```

FORTRAN IV G LEVEL 21          KMEANS          DATE = 7/3/68          09/24/81

      C ACCUMULATE THE TOTAL SCORE ON EACH VARIABLE FOR EACH CLUSTER
      DO 80 J=1,NC
      NJ=NUMR(J)
      J1=J1+NV
      DO 70 I=1,NV
      TOTAL(J1)=0.
      DO 80 K=1,NJ
      K=K+1
      NEMR(K)=J
      K1=(K-1)+NV
      DO 80 I=1,NV
      J2=J1+I
      TOTAL(J2)=TOTAL(J2)+DATA(K1+I)
      80 CONTINUE
      C COMPUTE THE CENTROIDS
      J1=0
      DO 90 J=1,NC
      DO 90 I=1,NV
      J1=J1+I
      C TEST FOR NUMR(J)=0
      CNTR(J)=TOTAL(J1)/NUMR(J)
      90 CONTINUE
      GO TO 115
      C INITIALIZE ARRAYS
      100 DO 110 K=1,NE
      110 NEMR(K)=0
      115 N=NRSS-1
      C BEGINNING OF MAIN LOOP
      120 J1=0
      DO 130 J=1,NCMAX
      NUMR(J)=0
      DO 130 I=1,NV
      J1=J1+I
      130 TOTAL(J1)=0.
      MOVE $00
      1307=0
      C ALLOCATE EACH DATA UNIT TO THE NEAREST CLUSTER CENTROID
      K1=0
      DO 140 K=1,NE
      K2=K1+1
      J2=1
      C COMPUTE DISTANCE TO FIRST CLUSTER CENTROID
      DRFF=DIS1(DATA(K2),CNTR(J2))
      SUM1=DRFF
      1407=1
      C TEST DISTANCES TO REMAINING CLUSTER CENTROIDS
      DO 140 J=2,NC
      J2=J2+NV
      DRFF=DIS1(DATA(K2),CNTR(J2))
      SUM1=SUM1+DRFF
      IF (DRFF .LT. DRFF1) GO TO 140
      DRFF=DRFF1
      1407=J

```

Figure A.7 (Part 2): Subroutine KMEAN2

MODELING OF SHADOWS IN RADAR CLUTTER

```

FORTRAN IV G LEVEL 21                                KMEAN2                                DATE = 79345                                09/24/01

0040      140  CONTINUE
0041      C  TEST FOR OUTLIERS, AND ALLOCATE NEW CLUSTERS IF ALLOWED.
0042      IF (LWHL, (ABS(LWHL-ADIST)) .LT. ABS(LWHL+ADIST))
0043      C  NEW CLUSTER
0044      NNEW=1
0045      JREF=NC
0046      DO 145 I=1,NV
0047      C  CONTINUE
0048      C  ALLLOCATE DATA UNIT NEW TO CLUSTER =JREF
0049      NUMBR(JREF)=NUMBR(JREF)+1
0050      IDIST=IDIST+TIMEP
0051      IF (JREF .EQ. MNBR(K)) GO TO 150
0052      C  THE DATA UNIT CHANGES ITS MEMBERSHIP
0053      MOVES=MOVES+1
0054      MNBR(K)=JREF
0055      J1=(JREF-1)/NV
0056      DO 160 I=1,NV
0057      K1=J1+I
0058      TOTAL(J1)=TOTAL(J1)+DATA(K1)
0059      CONTINUE
0060      C  ALL DATA UNITS ALLOCATED. TEST FOR CONVERGENCE
0061      WRITE(6,700) MOVES,NPASS,TDIST,NC
0062      NPASS=NPASS+1
0063      JREF=0
0064      IF (MOVES .GT. MNBR(1)) GO TO 185
0065      IF (METHOD .NE. 1) .AND. MOVES .EQ. 0) RETURN
0066      JREF=1
0067      C  COMPUTE TRUE CLUSTER CENTROIDS--FORGE UPDATE
0068      170  J1=0
0069      DO 180 J=1,NC
0070      DO 180 I=1,NV
0071      J1=J1+1
0072      IF (NUMBR(J) .LT. 0) GO TO 180
0073      CENTR(J1)=TOTAL(J1)/NUMBR(J)
0074      CONTINUE
0075      180  IF (JREF .EQ. 1) RETURN
0076      GO TO 125
0077      C
0078      185  IF (METHOD .NE. 1) GO TO 170
0079      C  JANCY UPDATE
0080      190  J1=0
0081      DO 200 J=1,NC
0082      DO 200 I=1,NV
0083      J1=J1+1
0084      C  TEST FOR NUMBR=0 HERE, TOO...
0085      200  CENTR(J1)=2.*TOTAL(J1)/NUMBR(J)-CENTR(J1)
0086      GO TO 120
0087      1000  FORMAT(23A4)
0088      1100  FORMAT(20I4)

```

```

FORTRAN IV G LEVEL 21                                KMEAN2                                DATE = 79345                                09/24/01

0123      2000  FORMAT(140,244)
0124      C  METHOD OF CLUSTER ANALYSIS. DATA SET STORED IN CORE
0125      C  REQUIRED STORAGE = 15 WORDS
0126      C  ALLOCATED STORAGE = 15 WORDS
0127      2100  FORMAT(10,20A4)
0128      C  INITIAL CLUSTER CENTERS READ IN AS FOLLOWS
0129      2200  FORMAT(1X,10*12,4)
0130      C  PART = 12, NUMBR ARRAY READ AS FOLLOWS
0131      2300  FORMAT(1X,10I7)
0132      C  DATA UNITS MOVED ON ITERATION NUMBR=13
0133      C  SUMMED DEVIATIONS ABOUT SEED POINTS = 16.210X, NC = 15
0134      END

```

Figure A.7 (Part 3): Subroutine KMEAN2

MODELING OF SHADOWS IN RADAR CLUTTER

```

PORTNAM IV 6 LEVEL 21          RESULT          DATE = 79365          10/29/05

0001      SUBROUTINE RESULT(CENTR,NUMBR,MEMBR,LIST,TITLE,NV,NC,NTOUT,
      & TOTAL,DATA)
C      THIS SUBROUTINE PRINTS THE RESULTS FROM A CLUSTERING JOB BASED
C      ON ANY VERSION OF SUBROUTINE "MEAN".
0002      DIMENSION CENTR(1),NUMBR(1),MEMBR(1),LIST(1),TITLE(20),TOTAL(1),
      & DATA(1)
C
C      AS A CONTINGENCY PRECAUTION WRITE OUT THE RAW MEMBERSHIP LIST.
0003      WRITE(6,2010) TITLE
0004      WRITE(6,2020) (MEMBR(K),K=1,NE)
0005      WRITE(6,2030) (NUMBR(J),J=1,NC)
C      INVERT THE "MEMBR" ARRAY AND PUT THE RESULT IN THE "LIST" ARRAY.
C      FIRST REVERSE THE "NUMBR" ARRAY TO CONTAIN START POINTS IN THE
C      "LIST" ARRAY FOR EACH CLUSTER
0006      NUMBR(NC)=NE-NUMBR(NC)+1
0007      JJ=NC
0008      JJ=JJ-1
0009      DO 10 J=2,NC
0010      NUMBR(JJ)=NUMBR(JJ)-NUMBR(JJ-1)
0011      JJ=JJ-1
0012      JJ=JJ-1
0013      10 CONTINUE
C      BUILD "LIST" ARRAY
0014      DO 20 K=1,NE
0015      MEMBRK=MEMBR(K)
0016      NJ=NUMBR(MEMBRK)
0017      LIST(NJ)=K
0018      NUMBR(MEMBRK)=NUMBR(MEMBRK)+1
0019      20 CONTINUE
C      SAVE THE SORTED MEMBERSHIP LIST IF DESIRED
0020      IF (NTOUT .LT. 0) GO TO 30
0021      WRITE (NTOUT,3000) TITLE
0022      WRITE (NTOUT,2100) (LIST(K),K=1,NE)
C      RESTORE THE "NUMBR" ARRAY.
0023      30      JJ=NC
0024      DO 40 J=2,NC
0025      NUMBR(JJ)=NUMBR(JJ)-NUMBR(JJ-1)
0026      JJ=JJ-1
0027      40 CONTINUE
0028      NUMBR(1)=NUMBR(1)-1
C      PRINT RESULTS FOR EACH CLUSTER
0029      WRITE(6,2000) TITLE
0030      K1=1
0031      DO 50 J=1,NC
0032      WRITE(6,2300) J,NUMBR(J)
0033      J1=(J-1)*NV
0034      WRITE(6,2400) (CENTR(J1+I),I=1,NV)
0035      K2=K1+NUMBR(J)-1
0036      WRITE(6,2500) (LIST(K),K=K1,K2)
0037      K1=K2+1
0038      50 CONTINUE
C      THIS DUMPS OUT "TOTAL" ARRAY

```

```

PORTNAM IV 6 LEVEL 21          RESULT          DATE = 79365          10/29/05

0039      DO 60 J=1,NC
0040      WRITE(6,4000) J
0041      4000      FORMAT(1--TOTALS FOR CLUSTER',I3)
0042      WRITE(6,4100) (TOTAL(I+J-1),J=1,NV)
0043      4100      FORMAT(1X,E10.5)
0044      60 CONTINUE
0045      RETURN
0046      2000      FORMAT(1M1,20A4)
0047      2100      FORMAT('RAW MEMBERSHIP LIST',/,(1X,25I5))
0048      2200      FORMAT('CLUSTER SIZES',/,(1X,25I5))
0049      2300      FORMAT('CLUSTER',I3,' CONTAINS',IS,' DATA UNITS')
0050      2400      FORMAT('CENTROID COORDINATES',/,(1X,10E12.4))
0051      2500      FORMAT('MEMBERSHIP LIST',/,(1X,25I5))
0052      3000      FORMAT(23A4)
0053      3100      FORMAT(16I5)
0054      END

```

Figure A.8: Subroutine RESULT

MODELING OF SHADOWS IN RADAR CLUTTER

```

UNTAN IV 6 LEVEL 21          RESULT          DATE = 79365          10/31/13

0001      SUBROUTINE RESULT2(CENTR,NUMBR,NMEMB,LIST,TITLE,T,NV,NC,NTOUT,
C      * TOTAL,DATA)
C      THIS SUBROUTINE PRINTS THE RESULTS FROM A CLUSTERING JOB BASED
C      ON ANY VERSION OF SUBROUTINE "MEAN".
0002      DIMENSION CENTR(1),NUMBR(1),MEMBR(1),LIST(1),TITLE(20),TOTAL(1),
C      * DATA(1)
C
C      AS A CONTINGENCY PRECAUTION WRITE OUT THE RAW MEMBERSHIP LIST.
0003      WRITE(6,2000) TITLE
0004      WRITE(6,2100) (MEMBR(K),K=1,NE)
0005      WRITE(6,2200) (NUMBR(J),J=1,NC)
C      INVERT THE "MEMBR" ARRAY AND PUT THE RESULT IN THE "LIST" ARRAY.
C      FIRST REVERSE THE "NUMBR" ARRAY TO CONTAIN START POINTS IN THE
C      "LIST" ARRAY FOR EACH CLUSTER
0006      NUMBR(NC)=NE-NUMBR(NC)+1
0007      JJ=NC
0008      JJ1=JJ-1
0009      DO 10 J=2,NC
0010      NUMBR(JJ1)=NUMBR(JJ)-NUMBR(JJ1)
0011      JJ=JJ1
0012      JJ1=JJ-1
0013      CONTINUE
10      BUILD "LIST" ARRAY
C      DO 20 K=1,NE
0014      MEMBRK=MEMBR(K)
0015      NJ=NUMBR(MEMBRK)
0016      LIST(NJ)=K
0017      NUMBR(MEMBRK)=NUMBR(MEMBRK)+1
0018      CONTINUE
20      SAVE THE SORTED MEMBERSHIP LIST IF DESIRED
C      IF (NTOUT.EQ.1) GO TO 30
0019      WRITE (NTOUT,3000) TITLE
0020      WRITE (NTOUT,3100) (LIST(K),K=1,NE)
0021      DO 22 K=1,NE
0022      CALL USRJUT(DATA((LIST(K)-1)*NV+1))
0023      RESTORE THE "NUMBR" ARRAY.
C      DO 40 J=1,NC
0024      JJ=NC
0025      DO 40 J=2,NC
0026      NUMBR(JJ)=NUMBR(JJ)-NUMBR(JJ-1)
0027      JJ=JJ-1
0028      CONTINUE
40      NUMBR(1)=NUMBR(1)-1
C      PRINT RESULTS FOR EACH CLUSTER
0029      WRITE(6,2000) TITLE
0030      K1=1
0031      DO 50 J=1,NC
0032      WRITE(6,2000) J,NUMBR(J)
0033      J1=(J-1)*NV
0034      WRITE(6,2400) (CENTR(J1+I),I=1,NV)
0035      K2=K1+NUMBR(J)-1
0036      WRITE(6,2500) (LIST(K),K=K1,K2)
0037      K1=K2+1
0038      CONTINUE
0039      K1=K2+1

```

```

FORTRAN IV 6 LEVEL 21          RESULT          DATE = 79365          10/31/13

0040      30      CONTINUE
C      THIS DUMPS OUT "TOTAL" ARRAY
0041      DO 60 I=1,NC
0042      WRITE(6,4000) I
0043      4000      FORMAT('---TOTALS FOR CLUSTER',I3)
0044      WRITE(6,4100) (TOTAL((I-1)*NV+J),J=1,NV)
0045      4100      FORMAT('---TOTALS FOR CLUSTER',I3)
0046      60      CONTINUE
0047      RETURN
0048      2000      FORMAT('111,POAM)
0049      2100      FORMAT('ORAY MEMBERSHIP LIST',/,(1X,25I5))
0050      2200      FORMAT('CLUSTER SIZES',/,(1X,25I5))
0051      2300      FORMAT('CLUSTER',I3,' CONTAINS',I5,' DATA UNITS')
0052      2400      FORMAT('CENTRID COORDINATES',/,(1X,10E12.4))
0053      2500      FORMAT('MEMBERSHIP LIST',/,(1X,25I5))
0054      3000      FORMAT('23AA)
0055      3100      FORMAT('1113)
0056      END

```

Figure A.9: Subroutine RESULT2

MODELING OF SHADOWS IN RADAR CLUTTER

```

FORTRAN IV G LEVEL 21          MAIN          DATE = 79365          11/19/01
C THIS IS THE DRIVING PROGRAM.  FURTHER DOCUMENTATION IN ROSCOE FILE "FCOM
C
0001      DIMENSION X(4000)
0002      LIMIT=4000
0003      CALL EXECR(X,LIMIT)
0004      END FILE 2
0005      STOP
0006      FNO

```

```

FORTRAN IV G LEVEL 21          DIST          DATE = 79365          11/19/01
0001      FUNCTION DIST(X,Y)
0002      DIMENSION X(1),Y(1)
0003      DIST=0
0004      DO 10 I=1,2
0005      DIST=DIST+(X(I)-Y(I))**2
0006      RETURN
0007      END

```

```

FORTRAN IV G LEVEL 21          USER          DATE = 79365          11/19/01
0001      SUBROUTINE USER(X)
0002      DIMENSION X(1)
0003      READ(4,100)(X(I),I=1,3)
0004      100  FORMAT(2F4.0,E17.10)
0005      RETURN
0006      END

```

```

FORTRAN IV G LEVEL 21          USEROUT       DATE = 79365          11/19/01
0001      SUBROUTINE USEROUT(X)
0002      DIMENSION X(1)
0003      WRITE(2,10)(X(I),I=1,3)
0004      10  FORMAT(2F4.0,E17.10)
0005      RETURN
0006      END

```

Figure A.10: MAIN; USER; USEROUT; Function DIST

MODELING OF SHADOWS IN RADAR CLUTTER

```

FORTRAN IV 6 LEVEL 21          MAIN          DATE = 80111      06/29/88
      C DRIVER. FURTHER USC. IN FILE 'PCOMMENT'
0001      DIMENSION X(24000)
0002      LIMIT=24000
0003      CALL EXEC_J(A,LIMIT)
0004      END FILE 4
0005      STOP
0006      END

```

```

FORTRAN IV 6 LEVEL 21          DIST          DATE = 80111      06/29/88
0001      FUNCTION DIST(X,Y)
0002      DIMENSION X(1),Y(1)
0003      C DISTANCE IS EUCLIDIAN (X-Y)
0004      DIST=0.0
0005      DO 10 I=1,2
0006      10 DIST=DIST+(X(I)-Y(I))**2
0007      RETURN
      END

```

```

FORTRAN IV 6 LEVEL 21          DIST          DATE = 80114      06/42/30
0001      FUNCTION DIST(X,Y)
0002      DIMENSION X(1),Y(1)
0003      C THIS DISTANCE FUNCTION ONLY USES THE THIRD VARIABLE--INTENSITY
0004      DIST=ABS(X(3)-Y(3))
0005      RETURN
      END

```

Figure A.11: MAIN; Two Versions of DIST

MODELING OF SHADOWS IN RADAR CLUTTER

```

FORTRAN IV G LEVEL 21          RAY          DATE = 79365      10/36/89

0001      SUBROUTINE RAY(IX,IY,VFL,SIGMA)
0002      IY=IX*65536
0003      IF (IY .GE. 0) GOTO 10
0004      IY=IY+2147483647+1
0005      VFL=IY
0006      VFL=VFL*.4656513E-9
0007      VFL=SQRT(-2.0*SIGMA**2*ALOG(1-VFL))
0008      IX=IY
0009      RETURN
0010      END

```

Figure A.12: Subroutine RAY

MODELING OF SHADOWS IN RADAR CLUTTER

```

FORTRAN IV G LEVEL 21          MAIN          DATE = 79365      10/26/16

0001      DIMENSION VALUE(100,100)
0002      SIGMA1=1.
0003      SIGMA2=10000.
0004      IX=123456789
0005      DO 100 I=1,100
0006      DO 100 J=1,100
0007      CALL RAY(I,X,Y,VFL,SIGMA1)
0008      VALUE(I,J)=VFL
0009      DO 1 I=1,100
0010      DO 1 J=1,100
0011      CALL RAY(I,X,Y,VFL,SIGMA2)
0012      1      VALUE(I,J)=VALUE(I,J)+VFL
0013      DO 2 I=20,30
0014      DO 2 J=1,30
0015      CALL RAY(I,X,Y,VFL,SIGMA2)
0016      2      VALUE(I,J)=VALUE(I,J)+VFL
0017      DO 3 I=20,30
0018      DO 3 J=51,100
0019      CALL RAY(I,X,Y,VFL,SIGMA2)
0020      3      VALUE(I,J)=VALUE(I,J)+VFL
0021      DO 4 I=31,50
0022      DO 4 J=1,100
0023      CALL RAY(I,X,Y,VFL,SIGMA2)
0024      4      VALUE(I,J)=VALUE(I,J)+VFL
0025      DO 5 I=60,80
0026      DO 5 J=1,50
0027      CALL RAY(I,X,Y,VFL,SIGMA2)
0028      5      VALUE(I,J)=VALUE(I,J)+VFL
0029      DO 6 I=60,80
0030      DO 6 J=71,100
0031      CALL RAY(I,X,Y,VFL,SIGMA2)
0032      6      VALUE(I,J)=VALUE(I,J)+VFL
0033      DO 7 I=81,100
0034      DO 7 J=1,100
0035      CALL RAY(I,X,Y,VFL,SIGMA2)
0036      7      VALUE(I,J)=VALUE(I,J)+VFL
0037      DO 300 I=1,100
0038      DO 300 J=1,100
0039      300      WRITE(1,500) I,J,VALUE(I,J)
0040      500      FORMAT(2I4,F17.10)
0041      END FILE 1
0042      WRITE(6,1000) IV
0043      1000      FORMAT(IX,I11)
0044      END

```

Figure A.13: Creates Rayleigh Data, SIGMA=10,000.

MODELING OF SHADOWS IN RADAR CLUTTER

```

FORTRAN IV G LEVEL 21          MAIN          DATE = 79365      11/03/21

0001      DIMENSION VALUE(100,100)
0002      SIGMA1=1.
0003      SIGMA2=50.
0004      IX=492247045
0005      DO 100 I=1,100
0006      DO 100 J=1,100
0007      CALL RAY(IX,IY,VFL,SIGMA1)
0008      VALUE(I,J)=VFL
0009      DO 1 I=1,10
0010      DO 1 J=1,100
0011      CALL RAY(IX,IY,VFL,SIGMA2)
0012      VALUE(I,J)=VALUE(I,J)+VFL
0013      DO 2 I=20,30
0014      DO 2 J=1,30
0015      CALL RAY(IX,IY,VFL,SIGMA2)
0016      VALUE(I,J)=VALUE(I,J)+VFL
0017      DO 3 I=20,30
0018      DO 3 J=51,100
0019      CALL RAY(IX,IY,VFL,SIGMA2)
0020      VALUE(I,J)=VALUE(I,J)+VFL
0021      DO 4 I=31,50
0022      DO 4 J=1,100
0023      CALL RAY(IX,IY,VFL,SIGMA2)
0024      VALUE(I,J)=VALUE(I,J)+VFL
0025      DO 5 I=50,80
0026      DO 5 J=1,50
0027      CALL RAY(IX,IY,VFL,SIGMA2)
0028      VALUE(I,J)=VALUE(I,J)+VFL
0029      DO 6 I=50,80
0030      DO 6 J=91,100
0031      CALL RAY(IX,IY,VFL,SIGMA2)
0032      VALUE(I,J)=VALUE(I,J)+VFL
0033      DO 7 I=81,100
0034      DO 7 J=1,100
0035      CALL RAY(IX,IY,VFL,SIGMA2)
0036      VALUE(I,J)=VALUE(I,J)+VFL
0037      DO 300 I=1,120
0038      DO 300 J=1,100
0039      WRITE(1,500) I,J,VALUE(I,J)
0040      FORMAT(24,F17.13)
0041      END FILE 1
0042      WRITE(6,1000) IY
0043      FORMAT(1X,I11)
0044      END

```

Figure A.14: Creates Rayleigh Data, SIGMA=50.

MODELING OF SHADOWS IN RADAR CLUTTER

```

FORTRAN IV G LEVEL 21          PLOT          DATE = 79365          10/02/11

0201      SUBROUTINE PLOT(IROW,JCOL)
0202      LOGICAL L1; DOX(255,151),CHARS(50),DOY
0203      DATA CHARS/11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,37,38,39,40,41,42,43,44,45,46,47,48,49,50,51,52,53,54,55,56,57,58,59,60,61,62,63,64,65,66,67,68,69,70,71,72,73,74,75,76,77,78,79,80,81,82,83,84,85,86,87,88,89,90,91,92,93,94,95,96,97,98,99,100,101,102,103,104,105,106,107,108,109,110,111,112,113,114,115,116,117,118,119,120,121,122,123,124,125,126,127,128,129,130,131,132,133,134,135,136,137,138,139,140,141,142,143,144,145,146,147,148,149,150,151,152,153,154,155,156,157,158,159,160,161,162,163,164,165,166,167,168,169,170,171,172,173,174,175,176,177,178,179,180,181,182,183,184,185,186,187,188,189,190,191,192,193,194,195,196,197,198,199,200,201,202,203,204,205,206,207,208,209,210,211,212,213,214,215,216,217,218,219,220,221,222,223,224,225,226,227,228,229,230,231,232,233,234,235,236,237,238,239,240,241,242,243,244,245,246,247,248,249,250,251,252,253,254,255,256,257,258,259,260,261,262,263,264,265,266,267,268,269,270,271,272,273,274,275,276,277,278,279,280,281,282,283,284,285,286,287,288,289,290,291,292,293,294,295,296,297,298,299,300,301,302,303,304,305,306,307,308,309,310,311,312,313,314,315,316,317,318,319,320,321,322,323,324,325,326,327,328,329,330,331,332,333,334,335,336,337,338,339,340,341,342,343,344,345,346,347,348,349,350,351,352,353,354,355,356,357,358,359,360,361,362,363,364,365,366,367,368,369,370,371,372,373,374,375,376,377,378,379,380,381,382,383,384,385,386,387,388,389,390,391,392,393,394,395,396,397,398,399,400,401,402,403,404,405,406,407,408,409,410,411,412,413,414,415,416,417,418,419,420,421,422,423,424,425,426,427,428,429,430,431,432,433,434,435,436,437,438,439,440,441,442,443,444,445,446,447,448,449,450,451,452,453,454,455,456,457,458,459,460,461,462,463,464,465,466,467,468,469,470,471,472,473,474,475,476,477,478,479,480,481,482,483,484,485,486,487,488,489,490,491,492,493,494,495,496,497,498,499,500,501,502,503,504,505,506,507,508,509,510,511,512,513,514,515,516,517,518,519,520,521,522,523,524,525,526,527,528,529,530,531,532,533,534,535,536,537,538,539,540,541,542,543,544,545,546,547,548,549,550,551,552,553,554,555,556,557,558,559,560,561,562,563,564,565,566,567,568,569,570,571,572,573,574,575,576,577,578,579,580,581,582,583,584,585,586,587,588,589,590,591,592,593,594,595,596,597,598,599,600,601,602,603,604,605,606,607,608,609,610,611,612,613,614,615,616,617,618,619,620,621,622,623,624,625,626,627,628,629,630,631,632,633,634,635,636,637,638,639,640,641,642,643,644,645,646,647,648,649,650,651,652,653,654,655,656,657,658,659,660,661,662,663,664,665,666,667,668,669,670,671,672,673,674,675,676,677,678,679,680,681,682,683,684,685,686,687,688,689,690,691,692,693,694,695,696,697,698,699,700,701,702,703,704,705,706,707,708,709,710,711,712,713,714,715,716,717,718,719,720,721,722,723,724,725,726,727,728,729,730,731,732,733,734,735,736,737,738,739,740,741,742,743,744,745,746,747,748,749,750,751,752,753,754,755,756,757,758,759,760,761,762,763,764,765,766,767,768,769,770,771,772,773,774,775,776,777,778,779,780,781,782,783,784,785,786,787,788,789,790,791,792,793,794,795,796,797,798,799,800,801,802,803,804,805,806,807,808,809,810,811,812,813,814,815,816,817,818,819,820,821,822,823,824,825,826,827,828,829,830,831,832,833,834,835,836,837,838,839,840,841,842,843,844,845,846,847,848,849,850,851,852,853,854,855,856,857,858,859,860,861,862,863,864,865,866,867,868,869,870,871,872,873,874,875,876,877,878,879,880,881,882,883,884,885,886,887,888,889,890,891,892,893,894,895,896,897,898,899,900,901,902,903,904,905,906,907,908,909,910,911,912,913,914,915,916,917,918,919,920,921,922,923,924,925,926,927,928,929,930,931,932,933,934,935,936,937,938,939,940,941,942,943,944,945,946,947,948,949,950,951,952,953,954,955,956,957,958,959,960,961,962,963,964,965,966,967,968,969,970,971,972,973,974,975,976,977,978,979,980,981,982,983,984,985,986,987,988,989,990,991,992,993,994,995,996,997,998,999,1000,1001,1002,1003,1004,1005,1006,1007,1008,1009,1010,1011,1012,1013,1014,1015,1016,1017,1018,1019,1020,1021,1022,1023,1024,1025,1026,1027,1028,1029,1030,1031,1032,1033,1034,1035,1036,1037,1038,1039,1040,1041,1042,1043,1044,1045,1046,1047,1048,1049,1050,1051,1052,1053,1054,1055,1056,1057,1058,1059,1060,1061,1062,1063,1064,1065,1066,1067,1068,1069,1070,1071,1072,1073,1074,1075,1076,1077,1078,1079,1080,1081,1082,1083,1084,1085,1086,1087,1088,1089,1090,1091,1092,1093,1094,1095,1096,1097,1098,1099,1100,1101,1102,1103,1104,1105,1106,1107,1108,1109,1110,1111,1112,1113,1114,1115,1116,1117,1118,1119,1120,1121,1122,1123,1124,1125,1126,1127,1128,1129,1130,1131,1132,1133,1134,1135,1136,1137,1138,1139,1140,1141,1142,1143,1144,1145,1146,1147,1148,1149,1150,1151,1152,1153,1154,1155,1156,1157,1158,1159,1160,1161,1162,1163,1164,1165,1166,1167,1168,1169,1170,1171,1172,1173,1174,1175,1176,1177,1178,1179,1180,1181,1182,1183,1184,1185,1186,1187,1188,1189,1190,1191,1192,1193,1194,1195,1196,1197,1198,1199,1200,1201,1202,1203,1204,1205,1206,1207,1208,1209,1210,1211,1212,1213,1214,1215,1216,1217,1218,1219,1220,1221,1222,1223,1224,1225,1226,1227,1228,1229,1230,1231,1232,1233,1234,1235,1236,1237,1238,1239,1240,1241,1242,1243,1244,1245,1246,1247,1248,1249,1250,1251,1252,1253,1254,1255,1256,1257,1258,1259,1260,1261,1262,1263,1264,1265,1266,1267,1268,1269,1270,1271,1272,1273,1274,1275,1276,1277,1278,1279,1280,1281,1282,1283,1284,1285,1286,1287,1288,1289,1290,1291,1292,1293,1294,1295,1296,1297,1298,1299,1300,1301,1302,1303,1304,1305,1306,1307,1308,1309,1310,1311,1312,1313,1314,1315,1316,1317,1318,1319,1320,1321,1322,1323,1324,1325,1326,1327,1328,1329,1330,1331,1332,1333,1334,1335,1336,1337,1338,1339,1340,1341,1342,1343,1344,1345,1346,1347,1348,1349,1350,1351,1352,1353,1354,1355,1356,1357,1358,1359,1360,1361,1362,1363,1364,1365,1366,1367,1368,1369,1370,1371,1372,1373,1374,1375,1376,1377,1378,1379,1380,1381,1382,1383,1384,1385,1386,1387,1388,1389,1390,1391,1392,1393,1394,1395,1396,1397,1398,1399,1400,1401,1402,1403,1404,1405,1406,1407,1408,1409,1410,1411,1412,1413,1414,1415,1416,1417,1418,1419,1420,1421,1422,1423,1424,1425,1426,1427,1428,1429,1430,1431,1432,1433,1434,1435,1436,1437,1438,1439,1440,1441,1442,1443,1444,1445,1446,1447,1448,1449,1450,1451,1452,1453,1454,1455,1456,1457,1458,1459,1460,1461,1462,1463,1464,1465,1466,1467,1468,1469,1470,1471,1472,1473,1474,1475,1476,1477,1478,1479,1480,1481,1482,1483,1484,1485,1486,1487,1488,1489,1490,1491,1492,1493,1494,1495,1496,1497,1498,1499,1500,1501,1502,1503,1504,1505,1506,1507,1508,1509,1510,1511,1512,1513,1514,1515,1516,1517,1518,1519,1520,1521,1522,1523,1524,1525,1526,1527,1528,1529,1530,1531,1532,1533,1534,1535,1536,1537,1538,1539,1540,1541,1542,1543,1544,1545,1546,1547,1548,1549,1550,1551,1552,1553,1554,1555,1556,1557,1558,1559,1560,1561,1562,1563,1564,1565,1566,1567,1568,1569,1570,1571,1572,1573,1574,1575,1576,1577,1578,1579,1580,1581,1582,1583,1584,1585,1586,1587,1588,1589,1590,1591,1592,1593,1594,1595,1596,1597,1598,1599,1600,1601,1602,1603,1604,1605,1606,1607,1608,1609,1610,1611,1612,1613,1614,1615,1616,1617,1618,1619,1620,1621,1622,1623,1624,1625,1626,1627,1628,1629,1630,1631,1632,1633,1634,1635,1636,1637,1638,1639,1640,1641,1642,1643,1644,1645,1646,1647,1648,1649,1650,1651,1652,1653,1654,1655,1656,1657,1658,1659,1660,1661,1662,1663,1664,1665,1666,1667,1668,1669,1670,1671,1672,1673,1674,1675,1676,1677,1678,1679,1680,1681,1682,1683,1684,1685,1686,1687,1688,1689,1690,1691,1692,1693,1694,1695,1696,1697,1698,1699,1700,1701,1702,1703,1704,1705,1706,1707,1708,1709,1710,1711,1712,1713,1714,1715,1716,1717,1718,1719,1720,1721,1722,1723,1724,1725,1726,1727,1728,1729,1730,1731,1732,1733,1734,1735,1736,1737,1738,1739,1740,1741,1742,1743,1744,1745,1746,1747,1748,1749,1750,1751,1752,1753,1754,1755,1756,1757,1758,1759,1760,1761,1762,1763,1764,1765,1766,1767,1768,1769,1770,1771,1772,1773,1774,1775,1776,1777,1778,1779,1780,1781,1782,1783,1784,1785,1786,1787,1788,1789,1790,1791,1792,1793,1794,1795,1796,1797,1798,1799,1800,1801,1802,1803,1804,1805,1806,1807,1808,1809,1810,1811,1812,1813,1814,1815,1816,1817,1818,1819,1820,1821,1822,1823,1824,1825,1826,1827,1828,1829,1830,1831,1832,1833,1834,1835,1836,1837,1838,1839,1840,1841,1842,1843,1844,1845,1846,1847,1848,1849,1850,1851,1852,1853,1854,1855,1856,1857,1858,1859,1860,1861,1862,1863,1864,1865,1866,1867,1868,1869,1870,1871,1872,1873,1874,1875,1876,1877,1878,1879,1880,1881,1882,1883,1884,1885,1886,1887,1888,1889,1890,1891,1892,1893,1894,1895,1896,1897,1898,1899,1900,1901,1902,1903,1904,1905,1906,1907,1908,1909,1910,1911,1912,1913,1914,1915,1916,1917,1918,1919,1920,1921,1922,1923,1924,1925,1926,1927,1928,1929,1930,1931,1932,1933,1934,1935,1936,1937,1938,1939,1940,1941,1942,1943,1944,1945,1946,1947,1948,1949,1950,1951,1952,1953,1954,1955,1956,1957,1958,1959,1960,1961,1962,1963,1964,1965,1966,1967,1968,1969,1970,1971,1972,1973,1974,1975,1976,1977,1978,1979,1980,1981,1982,1983,1984,1985,1986,1987,1988,1989,1990,1991,1992,1993,1994,1995,1996,1997,1998,1999,2000,2001,2002,2003,2004,2005,2006,2007,2008,2009,2010,2011,2012,2013,2014,2015,2016,2017,2018,2019,2020,2021,2022,2023,2024,2025,2026,2027,2028,2029,2030,2031,2032,2033,2034,2035,2036,2037,2038,2039,2040,2041,2042,2043,2044,2045,2046,2047,2048,2049,2050,2051,2052,2053,2054,2055,2056,2057,2058,2059,2060,2061,2062,2063,2064,2065,2066,2067,2068,2069,2070,2071,2072,2073,2074,2075,2076,2077,2078,2079,2080,2081,2082,2083,2084,2085,2086,2087,2088,2089,2090,2091,2092,2093,2094,2095,2096,2097,2098,2099,2100,2101,2102,2103,2104,2105,2106,2107,2108,2109,2110,2111,2112,2113,2114,2115,2116,2117,2118,2119,2120,2121,2122,2123,2124,2125,2126,2127,2128,2129,2130,2131,2132,2133,2134,2135,2136,2137,2138,2139,2140,2141,2142,2143,2144,2145,2146,2147,2148,2149,2150,2151,2152,2153,2154,2155,2156,2157,2158,2159,2160,2161,2162,2163,2164,2165,2166,2167,2168,2169,2170,2171,2172,2173,2174,2175,2176,2177,2178,2179,2180,2181,2182,2183,2184,2185,2186,2187,2188,2189,2190,2191,2192,2193,2194,2195,2196,2197,2198,2199,2200,2201,2202,2203,2204,2205,2206,2207,2208,2209,2210,2211,2212,2213,2214,2215,2216,2217,2218,2219,2220,2221,2222,2223,2224,2225,2226,2227,2228,2229,2230,2231,2232,2233,2234,2235,2236,2237,2238,2239,2240,2241,2242,2243,2244,2245,2246,2247,2248,2249,2250,2251,2252,2253,2254,2255,2256,2257,2258,2259,2260,2261,2262,2263,2264,2265,2266,2267,2268,2269,2270,2271,2272,2273,2274,2275,2276,2277,2278,2279,2280,2281,2282,2283,2284,2285,2286,2287,2288,2289,2290,2291,2292,2293,2294,2295,2296,2297,2298,2299,2300,2301,2302,2303,2304,2305,2306,2307,2308,2309,2310,2311,2312,2313,2314,2315,2316,2317,2318,2319,2320,2321,2322,2323,2324,2325,2326,2327,2328,2329,2330,2331,2332,2333,2334,2335,2336,2337,2338,2339,2340,2341,2342,2343,2344,2345,2346,2347,2348,2349,2350,2351,2352,2353,2354,2355,2356,2357,2358,2359,2360,2361,2362,2363,2364,2365,2366,2367,2368,2369,2370,2371,2372,2373,2374,2375,2376,2377,2378,2379,2380,2381,2382,2383,2384,2385,2386,2387,2388,2389,2390,2391,2392,2393,2394,2395,2396,2397,2398,2399,2400,2401,2402,2403,2404,2405,2406,2407,2408,2409,2410,2411,2412,2413,2414,2415,2416,2417,2418,2419,2420,2421,2422,2423,2424,2425,2426,2427,2428,2429,2430,2431,2432,2433,2434,2435,2436,2437,2438,2439,2440,2441,2442,2443,2444,2445,2446,2447,2448,2449,2450,2451,2452,2453,2454,2455,2456,2457,2458,2459,2460,2461,2462,2463,2464,2465,2466,2467,2468,2469,2470,2471,2472,2473,2474,2475,2476,2477,2478,2479,2480,2481,2482,2483,2484,2485,2486,2487,2488,2489,2490,2491,2492,2493,2494,2495,2496,2497,2498,2499,2500,2501,2502,2503,2504,2505,2506,2507,2508,2509,2510,2511,2512,2513,2514,2515,2516,2517,2518,2519,2520,2521,2522,2523,2524,2525,2526,2527,2528,2529,2530,2531,2532,2533,2534,2535,2536,2537,2538,2539,2540,2541,2542,2543,2544,2545,2546,2547,2548,2549,2550,2551,2552,2553,2554,2555,2556,2557,2558,2559,2560,2561,2562,2563,2564,2565,2566,2567,2568,2569,2570,2571,2572,2573,2574,2575,2576,2577,2578,2579,2580,2581,2582,2583,2584,2585,2586,2587,2588,2589,2590,2591,2592,2593,2594,2595,2596,2597,2598,2599,2600,2601,2602,2603,2604,2605,2606,2607,2608,2609,2610,2611,2612,2613,2614,2615,2616,2617,2618,2619,2620,2621,2622,2623,2624,2625,2626,2627,2628,2629,2630,2631,2632,2633,2634,2635,2636,2637,2638,2639,2640,2641,2642,2643,2644,2645,2646,2647,2648,2649,2650,2651,2652,2653,2654,2655,2656,2657,2658,2659,2660,2661,2662,2663,2664,2665,2666,2667,2668,2669
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MODELING OF SHADOWS IN RADAR CLUTTER

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FORTHAN IV G LEVEL 21          MAIN          DATE = 00010      00/35/66

0001      C GRAY SCALE PROGRAM...
0002      INTGEN=0,GRAY
0003      REAL XLINE(120),THRESH(8)
0004      LOGICAL SCALE(1),PLINE(120)
0005      C HEAD IN THE GRAY SCALE SYMBOLS...
0006      HEAD(5,5)(SCALE(1),I=1,8)
0007      FORMAT(A1)
0008
0009      C
0010      C
0011      C READ THE LOWEST VALUE FOR EACH GRAY LEVEL.
0012      DO 10 I=2,8
0013      READ(5,100) THRESH(I)
0014      I1=I-1
0015      WRITE(6,101) SCALE(I1),THRESH(I1)
0016      10 CONTINUE
0017      C HEAD MAX 1012, AND VE-1, AXIS VALUES. (<= 120; <= 256)
0018      WRITE(5,102) SCALE(1),THRESH(8)
0019      READ(5,201) MAXV,MAXH
0020      WRITE(6,201) MAXV,MAXH
0021      DO 20 J=1,MAXV
0022      DO 30 K=1,MAXH
0023      READ(1,300) XLINE(J)
0024      GRAY=1
0025      DO 40 K=2,8
0026      IF (XLINE(J) .LE. THRESH(K)) GO TO 40
0027      GRAY=K
0028      40 CONTINUE
0029      PLINE(J)=SCALE(GRAY)
0030      30 CONTINUE
0031      WRITE(6,103)(PLINE(J),J=1,MAXH)
0032      20 CONTINUE
0033      STOP
0034      100 FORMAT(F15.7)
0035      101 FORMAT(' SYMBO...',A1,..., '<.',F15.7)
0036      102 FORMAT(' SYMBO...',A1,..., '>.',F15.7)
0037      201 FORMAT(' MAXV=',I4,' MAXH=',I4,'.')
0038      300 FORMAT(' ',I20A1)
0039      400 FORMAT('K.E12.7')
0040      END

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FIGURE A.16: Grey Scale Program

MODELING OF SHADOWS IN RADAR CLUTTER

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